8-1975

Sedimentation and Stratigraphy of the Rome Formation in East Tennessee

Nabil Fahmi Samman
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To the Graduate Council:

I am submitting herewith a dissertation written by Nabil Fahmi Samman entitled "Sedimentation and Stratigraphy of the Rome Formation in East Tennessee." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Geology.

Garrett Briggs, Major Professor

We have read this dissertation and recommend its acceptance:

Robert E. McLaughlin, Kenneth R. Walker, Theodore H. Schmadde

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Vice Chancellor
Graduate Studies and Research

SEDIMENTATION AND STRATIGRAPHY OF THE ROME FORMATION IN EAST TENNESSEE

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee

Nabil Fahmi Samman

August 1975

To my wife

Safiya

and daughter

Lama

ABSTRACT

The late Early Cambrian Rome Formation is the oldest formation that is exposed widely across the Valley and Ridge Province. It is brought to the surface by major thrust faults, and in many cases is topographically the highest exposed formation; consequently, the bottom and the top of the Rome are usually missing. Nowhere is a complete section of the Rome Formation exposed except in northeast Tennessee.

The Rome is a heterogeneous formation of red, maroon, brown and green colored sandstone, siltstone and shale and local beds of gray limestone and dolomite, all of which vary greatly in proportion and distribution throughout the formation. Sandstone and siltstone predominate in the northwestern belts of the Appalachian Valley with lesser amounts of shale and carbonates, while to the southeast shales predominate and carbonates make up approximately half of the formation, thus indicating a western source for the Rome sediments. This is confirmed by clastic ratios, and paleocurrent measurements of cross-bedding and ripple marks in the study area.

A striking feature of the Rome Formation is the abundance of primary sedimentary and organic structures. Sedimentary structures which point to a tidal flat type of environment are: mud cracks, halite crystal casts, ripple marks, rain prints, tidal balls, current lamination, ripple lamination, flaser and lenticular bedding. Biogenic sedimentary structures are found throughout the formation of which the most important environmental indicators are _Scoyenia_ (supratidal), _Skolithos_ (beach) and _Cruziana_ (Supratidal to subtidal). _Cruziana_ in the Rome Formation does not fit Seilacher's ichnofacies model in which _Cruziana_ is confined to the sudtidal zone.

Evidence from the Rome sediments indicates that they were deposited in the following environments: supratidal, mud flat, mixed flat, sandflat, tidal flat gullies, lagoon and oolite shoals. The general coarsening upward in the Rome indicates a general transgressive sequence. The transgressive and regressive phases within the Rome sections can be correlated across strike.

Previous studies of the Rome have indicated that the formation is difficult to correlate due to the scarcity of fossils and absence of marker beds. The present study indicates that there are marker beds at the top of the formation and that the Rome can be correlated easily for a distance of 40 km along Pine Ridge and for lesser distances along other ridges. Across strike the formation can be correlated with difficulty over a palinspastic distance of 105 km by utilizing the oolite and Skolithos zones as markers.

The Pumpkin Valley Shale which is Middle Cambrian in age is a facies equivalent of the upper Rome, while the top of the Shady Dolomite is a facies equivalent of the lower part of the Rome. Thus the Rome is of late Early Cambrian age in the Appalachian Valley and probably Middle Cambrian in the subsurface in central Tennessee where it lies nonconformably over the Precambrian basement. The sea advanced over the craton in the present position of the Appalachian Valley during Rome time. The craton had been previously peneplained and deeply weathered in a tropical to subtropical climate. The weathered products were transported and deposited in the Rome sea and tidal flats.

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CHAPTER I

INTRODUCTION

Purpose of Investigation

Objectives of this investigation are listed as follows: (1) To describe in detail the lithology of the Rome Formation, locate any marker beds, and, through detailed stratigraphic logging and thin sectioning, report and explain lithologic, sedimentary and biogenic features. (2) To establish the interrelationship of the different lithologies within the Rome, and to attempt correlation of stratigraphic sections parallel to and across strike. (3) To determine the nature of the relationship between the Rome, Shady Dolomite, and Pumpkin Valley Shale formations. (4) To reconstruct the environments of deposition with the aid of sedimentary and biogenic structures in the formation, and, consequently identify transgressive and regressive sequences. (5) To determine the source and paleocurrent direction of the Rome sediments through sand/shale and clastic ratios, and measurement of cross-bedding and current ripple directions. (6) To draw a paleoenvironmental model for the Rome from ichnofossils and compare it to Seilachier's ichnofacies model. (7) To describe the Cambrian paleogeography during the time of deposition of this formation.

Geologic Setting

The Lower Cambrian Rome Formation crops out in the Valley and Ridge Province, as a series of long, narrow resistant ridges that parallel the generally northeast - southwest regional strike. The area of study (Figure 1) is part of the Valley of East Tennessee, a subdivision of the Valley and Ridge Province that extends from northeast New York State to central Alabama, a distance of 1920 km (1200 miles) and ranges in width from 32 to 120 km (Figure 2). The Valley of East Tennessee, known also as the Appalachian Valley, is bounded on the east by the Blue Ridge Province (Figure 2) which is characterized by high rugged mountain topography with elevations of up to 1980 m (6,600 feet). The boundary between the Valley and Ridge and Blue Ridge provinces is a zone of intense overthrusting and folding in the southern Appalachians. Rocks in the Blue Ridge range in age from Precambrian to Triassic, and consist of granites, schists, gneisses, quartzites, conglomerates, slates, and marbles. To the west, the Appalachian Valley is bounded by the abrupt escarpment of the Cumberland Plateau. The Plateau has a dissected undulating surface which is 450 to 1050 m (1500 to 3500 feet) above mean sea level. Plateau rocks consist of Pennsylvanian sandstones, shales, and coal beds, mainly, underlain by Mississippian limestones and shales and older Paleozoic rocks. Strata in this plateau are nearly horizontal, except in the Sequatchie Valley where rocks have been compressed into well defined folds.

The boundaries between the three provinces are structural as well as topographic. The relationship between these provinces is that at the boundaries older rocks are thrust over younger sediments, and from the Blue Ridge through the Appalachian Valley to the Cumberland Plateau the exposed sedimentary rocks become progressively younger in age. Precambrian to Lower Cambrian in the Blue Ridge, Early Cambrian to Pennsylvanian in the Appalachian Valley and Silurian to Pennsylvanian in the

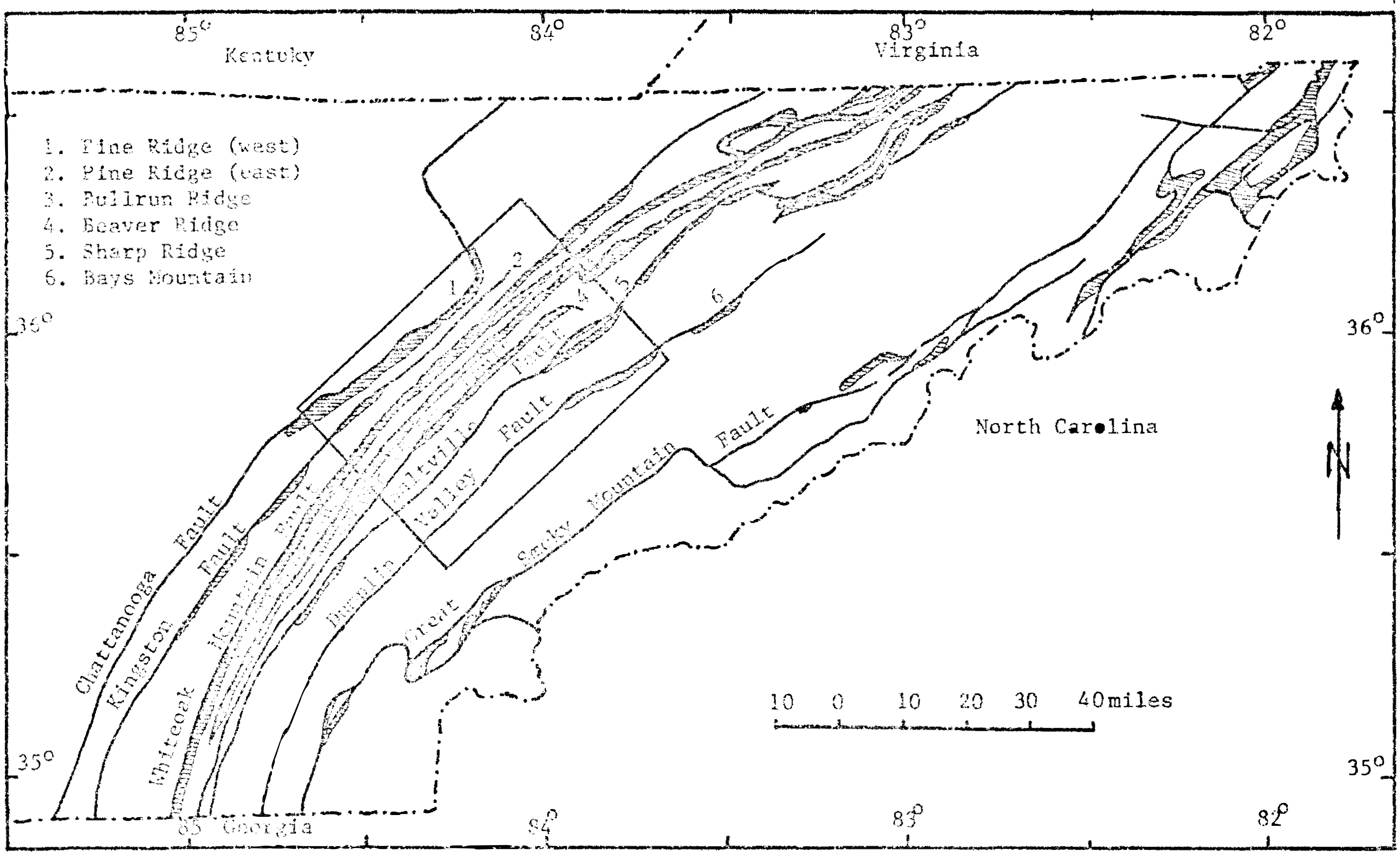

Figure 1. Distribution of the Rome Formation in East Tennessee. The area of investigation is within rectangle.

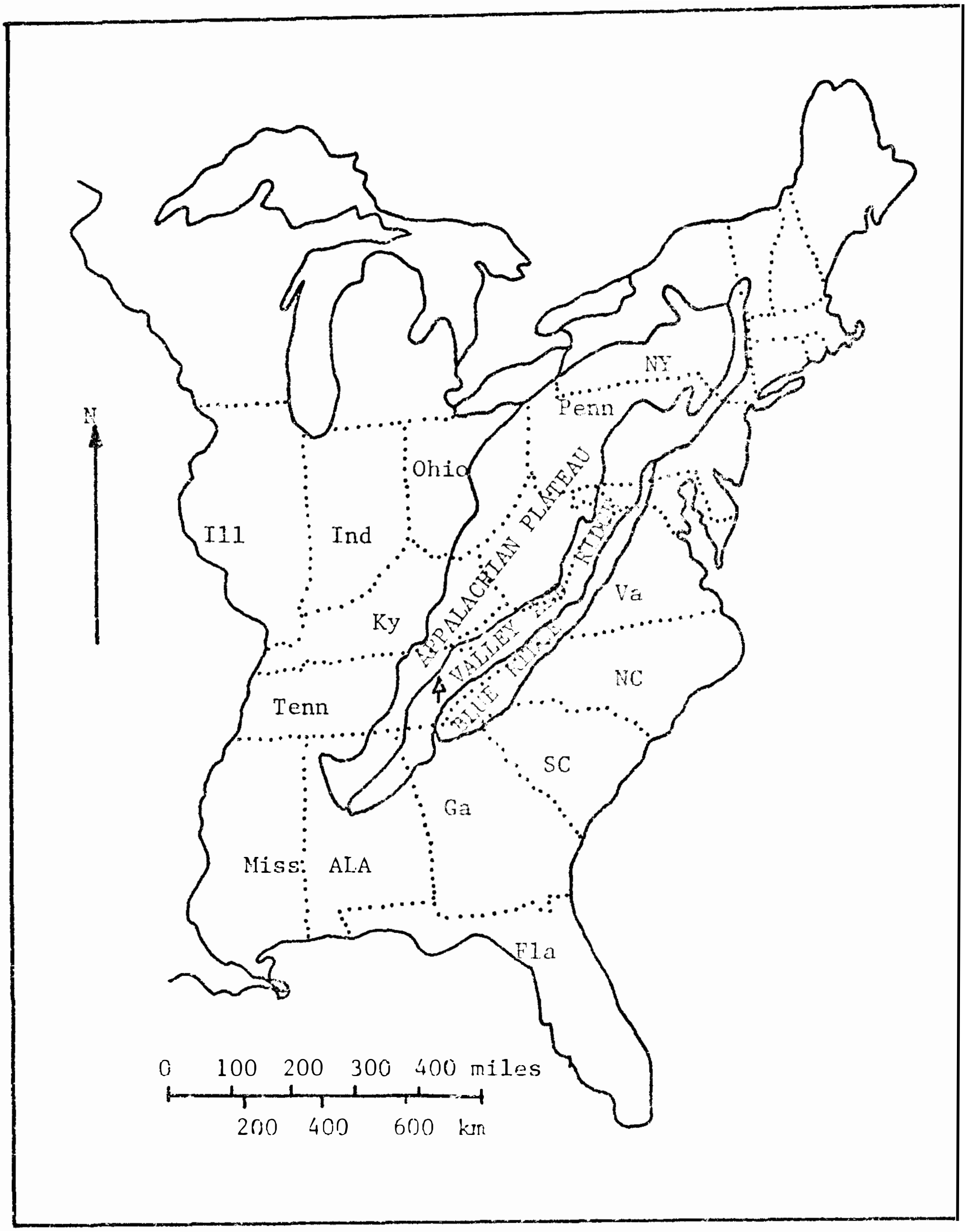

Figure 2. The Valley and Ridge Province with adjacent provinces in the eastern United States. Arrow points to area of study.

Cumberland Plateau. Thus there is a facies relationship also between the three provinces.

The Appalachian Valley is characterized by narrow parallel ridges and somewhat broader northeast - southwest trending intervening valleys. Elevations of the valley floors and ridge summits decrease progressively from northeast to southwest, as streams and rivers draining into the Tennessee River become mature southwest-ward. Ridges underlain by the Rome Formation are sharp and steep due to the abundance of resistant sandstone beds, while ridges underlain by shales, limestones and dolomites of the Conasauga, Knox and Chicamauga groups are broader and less extreme topographically. The ridges range in width from 1 to 3 km and are broken by water gaps and wind gaps. In the extreme northeastern part of the region, the valleys are narrow and range in elevation from 600 to 750 m (2000 to 2500 feet) above sea level, and the ridges stand at elevations of 1200 to 1350 m (4000 to 4500 feet). In the vicinity of Knoxville, the valleys range in elevation from 240 to 300 m (800 to 1000 feet), while the higher ridges are 330 to 450 m (1100 to 1500 feet) high.

Geologically, the Appalachian Valley is characterized by folded and homoclinal thrust sheets. Outcrops of the formations in the Appalachian Valley are repeated several times from southeast to northwest in narrow linear northeast striking belts. This outcrop pattern is the result of folding and faulting of strata in the Late Paleozoic, followed by the removal by erosion or sometimes persistance of the upper portions of the resulting structures. The structure of the Appalachian Valley is characterized by a series of overlapping linear thrust sheets which dip to the southeast (Figure 3). Sedimentary rock layers in the valley are

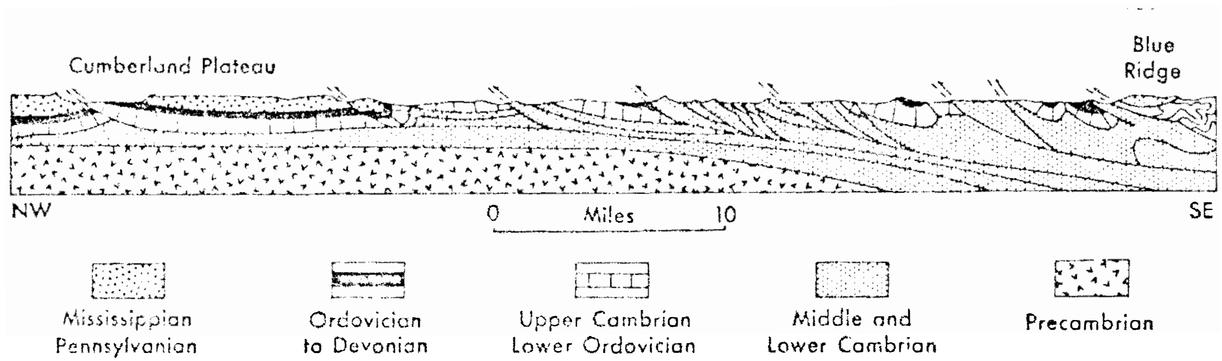

Figure 3. Cross-section of the Valley and Ridge Province in Tennessee (Rodgers 1964).

unmetamorphosed. These rocks consist mainly of limestones, dolomites and calcareous shales with abundant arenaceous and argillaceous shales and sandstones. Rocks exposed are mainly Lower Cambrian to Ordovician over most of the Valley, except at the northwestern edge where Silurian to Pennsylvanian age rocks are exposed.

Distribution of the Rome Within the Appalachian Valley

The Rome Formation in Tennessee is exposed extensively in the Appalachian Valley (Figure 1, page 3). It is the oldest formation that crops out in the Valley, but in the belt of mountains to the east of the valley it is the youngest formation exposed. It is found in small fault slices at the western foot of the Smoky Mountains, but from Bays Mountain and to the west, the formation underlies the prominent ridges in the valley. The ridge topography is maintained by the presence of resistant quartzitic sandstone layers in the formation.

The banded outcrop pattern of the Rome is due to thrust faulting which brought to the surface thrust sheet after thrust sheet in which the Rome is the oldest formation. In all cases, except in northeastern Tennessee, the thrust faults cut through the upper half of the Rome. Thus nowhere in the valley is the bottom of the formation exposed. This fact most probably indicates that the Rome lies directly on the Precambrian basement in the Valley and Ridge Province in Tennessee, because the basement is not believed to be involved in this deformation. No deep wells have penetrated the basement in this region to prove this point, but in Central Tennessee and Kentucky, the Rome immediately overlies the basement in the subsurface (Harris, 1964).

The stratigraphic position of the Rome is above the Shady Dolomite, the Precambrian basement, and under the Pumpkin Valley Shale (Figure 4). In northeast Tennessee, where the only continuous section of the Rome is found at Valley Forge, the Rome Formation is overlain by the Honaker Dolomite (Plate 6). (All plates are in pocket.) In the Appalachian Valley, the resistant and steeply dipping beds of the Rome are topographically the highest beds in a ridge, while the Pumpkin Valley Shale is found at the down-dip of the ridges or in the valleys, hence the top of the Rome is sometimes eroded or covered. The exact thickness of the Rome in the valley is not known, but deep basement wells in Central Tennessee and Kentucky indicate that the Rome thins and wedges out westward.

Description of Study Area

The area of study is in the western part of the Appalachian Valley. It extends from Lake City in the northwest to Bays Mountain in the southeast, and from House Mountain in the northeast to Harriman in the southwest (Figure 5), an area of 4350 sq km (1700 square miles).

This area is characterized by alternating valleys and ridges which strike northeast. The prominent ridges of the Rome exhibit a characteristic comby topography. The ridges have an average elevation of 300 m (1000 feet) above sea level with a relief of 90 to 150 m (300 to 500 feet) above the surrounding valleys. These Rome ridges, from east to west are: Bays Mountain, Sharp Ridge, Beaver Ridge, Bullrun Ridge, Pine Ridge (east) and Pine Ridge (west). The area is drained by the Tennessee River, Clinch River, French Braod River, the Holston River and numerous creeks. These rivers flow parallel to and across the

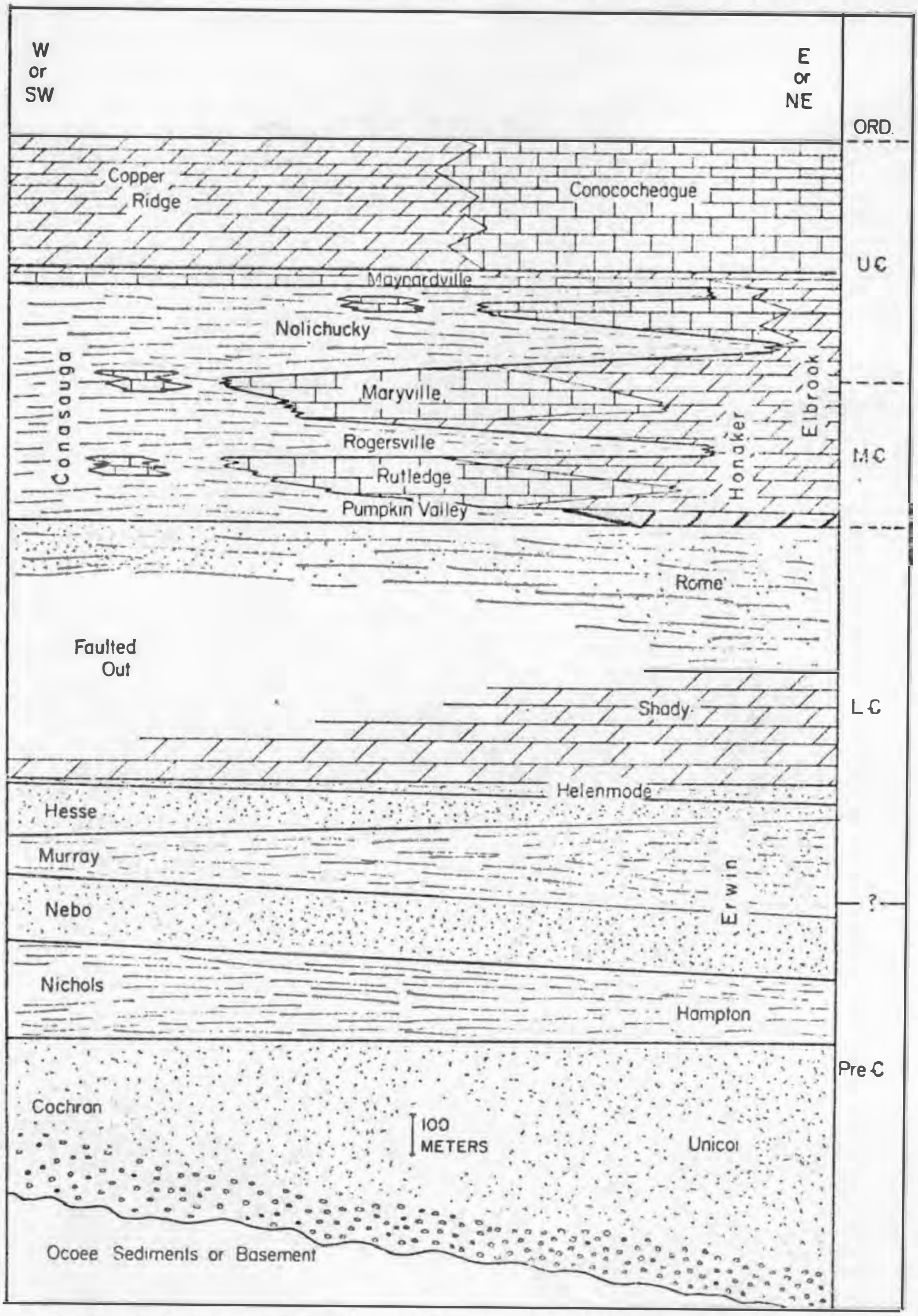

Figure 4. Correlation and facies relationship of Cambrian rocks in Tennessee (Palmer 1970).

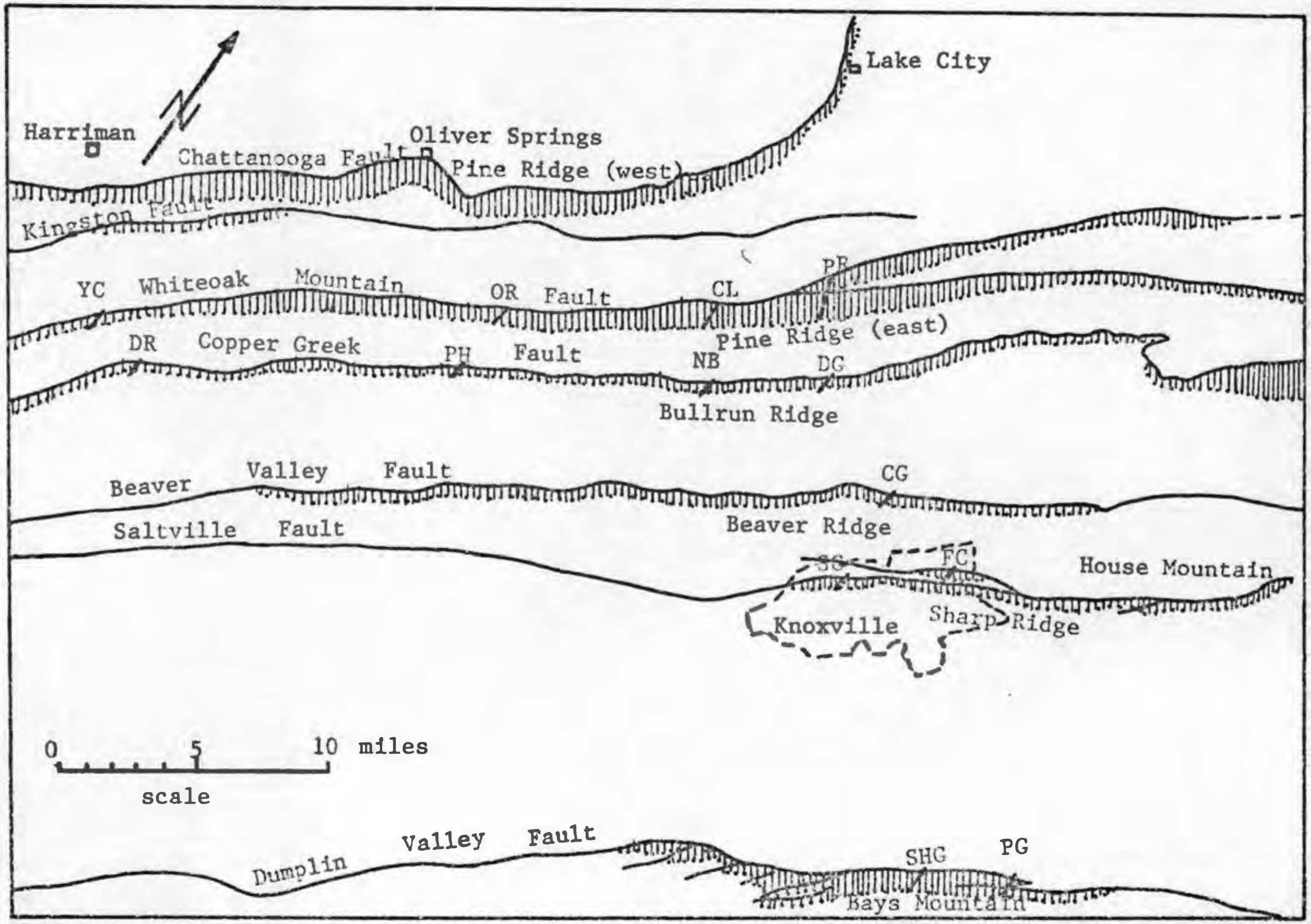

Figure 5. Rome exposures in study area. For detailed location see table 1.

ridges forming water gaps through which the highways and railroads run. Diggs Gap, Crippen Gap, Sharp Gap and Porterfield Gap are some of the water and dry gaps where the Rome Formation is exposed.

The clastics and carbonates in the Rome Formation weather differently, with sandstone, siltstone and shale beds dominating the residuum and soil which forms a shallow mantle full of rock chips. The carbonate rocks weather more deeply, and locally form zones of grayish orange silty clay with a reddish brown soil layer.

The area is accessible through a network of highways and roads. Some of the best Rome exposures are along Interstate 40 which runs east - west and Interstate 75 which runs north - south across the study area. Most of the outcrops studied are within 40 km (25 miles) of the City of Knoxville which is near the center of the area.

Rome Outcrops

Thirteen sections have been studied in detail. The locations of the sections are shown in Figure 5 and Table 1. These outcrops were chosen after the author examined all the roads that cross Rome ridges in the study area. No Rome exposures were found along Pine Ridge (west), while along Pine Ridge (east) only four outcrops are well exposed. These are at Pine Ridge I-75, Clinton, Oak Ridge and Young Creek. The Bullrun Ridge belt offered more than six outcrops, the best four of which are Diggs Gap, Nelson Branch, Pumphouse Road and Dug Ridge. The only well exposed section in Beaver Ridge is at Crippen Gap. Although it exhibits numerous incomplete or covered sections, Sharp Ridge provides only one satisfactory exposure for this investigation, at Sharp Gap. The First

Table 1. Detailed Location of Rome Exposures in the Study Area.

	Section	County	Quadrangle	Coordinates	Thickness in Meters	Rome/Pumpkin Valley Contact	Quality
1.	Pine Ridge I-75 (PR)	Anderson	Powell Station	36° 6' 30"N 86° 5' 0"W	286	Clear	Very good
2.	Clinton (CL)	Anderson	Clinton	36° 3' 42 N 84° 7' 31"W	53	Covered	Poor
3.	Oak Ridge (OR)	Anderson	Clinton	36° 0' 8"N 84° 14' 0"W	160	Covered	Good
4.	Young Creek (YC)	Roane	Cave Creek	35° 52' 29"N 84° 27' 0"W	88	Exposed	Good
5.	Diggs Gap (DG)	Knox	Powell Station	36° 6' 0"N 84° 1' 20"W	107	Exposed	Fair
6.	Nelson Branch (NB)	Anderson	Powell Station	36° 2' 0"N 84° 6' 0"W	50	Exposed	Poor
7.	Pumphouse Road (PH)	Anderson	Lovell	36° 58' 30"N 84° 13' 0"W	54	Exposed	Poor
8.	Dug Ridge (DR)	Roane	Cave Creek	35° 52' 0"N 84° 25' 0"W	90	Covered	Fair
9.	Crippen Gap (CG)	Knox	Fountain City	36° 4' 0"N 83° 55' 30"W	91	Exposed	Good

Table 1. (Continued)

	Section	County	Quadrangle	Coordinates	Thickness in Meters	Rome/Pumpkin Valley Contact	Quality
10.	First Creek (FC)	Knox	Fountain City	36° 1' 15"N 83° 55' 30"W	53	Exposed	Poor
11.	Sharp Gap (SG)	Knox	Knoxville	35° 59' 40"N 83° 57' 10"W	78	Exposed	Good
12.	Porterfield Gap (PG)	Knox/ Sevier	Boyds Creek	35° 55' 0"N 83° 43' 10"W	334	Covered	Very good
13.	Shooks Gap (SHG)	Knox/ Sevier	Shooks Gap	35° 53' 0"N 83° 47' 31"W	60	Covered	Poor

Creek section in Sharp Ridge is relatively poor. Bays Mountain provides only two roadcuts, the Porterfield Gap section and the Shooks Gap section. No exposures outside the study area were examined because the sections studied are homogeneously distributed within the area. Published sections and basement well logs outside the area of study were utilized in determining facies and thickness trends across strike.

Structure

Several southeastward dipping thrust faults in the study area (Figure 1, page 3) thrust the Rome Formation northwestward. The age of the faulting in the Appalachian Valley is post Pennsylvanian, as indicated by the fact that Pennsylvanian formations at the western edge of the valley are fault-involved.

The amount of dip on the Rome beds in the study area varies from 10° to about 90°, with the majority of beds dipping at angles between 30° to 50° southeastward. The dip is constant in any one section except where there is folding as in the Clinton, Shooks Gap and Porterfield Gap sections. Overturned beds due to a combination of thrusting and folding within the Rome Formation are found at the Clinton and Pumphouse Road sections. The strike of Rome beds is uniformly northeastward and varies within the study area from $N40^{\circ}E$ to $N60^{\circ}E$.

The thrust faults that brought the Rome Formation to the surface, are, from east to west, the Dumplin Valley, Saltville, Beaver Valley, Copper Creek, Whiteoak Mountain, Kingston and Chattanooga faults (Figure 1, page 3). The Chattanooga fault brought the Rome into contact with rocks ranging in age from the Middle Cambrian Conasauga Shale to the lower Pennsylvanian shale, sandstone and coal beds (Swingle, 1960c). Thus the stratigraphic throw is 600 to 3000 m (2000 to 10,000 feet), while the Kingston fault, which brought slices of the Rome into contact with the Conasauga Shale and Knox Dolomite, has a stratigraphic displacement of 600 to 1200 m (2000 to 4000 feet). According to Rodgers (1970), the Kingston fault is an offshoot of the Chattanooga fault and the displacements on these faults are of the same order. Horizontal displacement calculated by the author from structural sections by Swingle (1960c) in the Lake City Quadrangle indicate that the minimum movement on these faults is about 8 km (5 miles).

The Whiteoak Mountain fault thrust the Rome over rocks ranging in age from Middle Cambrian to Silurian (Swingle, 1966). The fault trace, the bottom of the Rome, and the overthrust formations in the exposures studied along Pine Ridge (east) are covered. These outcrops are the least disturbed by folding or faulting of all sections examined except the Clinton section. The stratigraphic throw is 600 to 2250 m (2000 to 7500 feet) and the horizontal displacement according to D. H. Roeder (1975) is 35 km (22 miles) northwestward.

The Copper Creek fault which thrust the Rome over the Middle Ordovician Chicamauga Limestone, has a stratigraphic throw of about 2000 m (6000 feet) and a horizontal displacement of 14 km (8.7 miles) (D. H. Roeder, 1975). The fault in all outcrops studied along Bullrun Ridge, is a bedding plane thrust fault which dips at a minimum angle of 30° southeastward. Within the Rome sections there are branches of this fault that cut through the formation, complicating the stratigraphy and deforming many units, but there is no evidence of repetition of beds.

A good example is the Diggs Gap section which has five faults, numerous fractures and small scale drag folding in some alternate sandstone and shale units.

At Crippen Gap the Rome Formation is thrust by the Beaver Valley fault over the Lower Ordovician Knox Dolomite. Thus the stratigraphic throw is about 1800 m (6000 feet) while the horizontal displacement northwestward is 9 km (5.6 miles) (D. H. Roeder, 1975). The fault plane separating the Rome from the Knox Dolomite is sharp and dips steeply towards the southeast. There are two branches of the Beaver Valley fault within the Rome Formation, but only the bottom dolomite units are brecciated and fractured.

At Sharp Ridge the Saltville fault has thrust the Rome northwestward about 34 km (21 miles) (D. H. Roeder, 1975). The rocks below the fault are of the Lower Ordovician Knox Dolomite, suggesting a stratigraphic throw of 1800 m (6000 feet). The fault and the overlying beds dip steeply towards the southeast. The Saltville fault trace at the First Creek section is seen as a sharp contact between the Rome and the Knox, but at Sharp Gap the fault trace is within a 10 meter-wide brecciated zone. This faulting has produced intense drag folding in alternating sandstone and shale units in the First Creek section.

The Dumplin Valley fault thrusts the Rome northwestward about 9 km (5.6 miles) (D. H. Roeder, 1975) over the Lower Ordovician Knox Dolomite at Shooks Gap and the Middle Cambrian Conasauga Shale at Porterfield Gap (Swingle, 1966). Thus the stratigraphic throw is 360 to 1800 m (1200 to 6000 feet). The fault trace in both sections is covered as well as the bottom of the Rome and the overthrust formations. According to Rodgers

(1953) the Rome at Shooks Gap is thrust over the Knox Dolomite, while Cattermole (1955) shows the Rome in conformable contact with the underlying Shady Dolomite. This exposure is intensely distorted by folding and faulting with beds dipping from a low angle to nearly vertical. The Porterfield Gap section is faulted and foleded, and the entire exposure comprises a large anticline.

Previous Work

Many geologic studies conducted in the Appalachian Valley include references to the Rome Formation; however, few of these studies concentrated on the Rome. James Safford (1869) applied the name "Knox Sandstone" to the lithology now called Rome as a separate unit forming the basal part of his Knox Group. Hayes (1891) renamed the formation for its exposure in Coosa Valley south of Rome, Georgia. The exposure he described became the type locality for the Rome Formation. Later, in 1894 (a), he subdivided the formation into an upper "Rome Shale" and lower "Rome Sandstone." Hayes (1894b, 1894c, 1895) together with Keith (1895) recognized a unit of shale with no sandstone below the top of the lower "Rome Sandstone" and called it the "Apison Shale" from exposures at Apison, Hamilton County, Tennessee. Hayes (1894a) estimated a thickness of 900 to 1200 m (3000 to 4000 feet) for the Rome in the Ringgold folio. Keith in his geologic folios (1895, 1896a, 1896b, 1896c, 1901, 1903, 1907a, 1907b) mapped the Rome Formation, and applied the term "Watauga Shale" to the dolomites and red shales overlying the "Shady Dolomite" as the Rome equivalent in northeast Tennessee. Woodward (1929) suggested keeping the term "Watauga Shale" as a facies of the Rome

Formation. Keith (1895) mapped a 91 m (300 feet) dolomite unit within the Rome Formation on Bays Mountain as the "Beaver Limestone" from its occurrence in Beaver Ridge north of Knoxville. However, in 1901 he did not map this unit separately on Beaver Ridge, so the term was abandoned. Hayes (1902) followed Keith and mistakenly applied the term "Beaver Limestone" for the "Shady Dolomite" in Georgia and Alabama. Smith (1890) assigned the term "Montevallo Formation" to exposures of Rome lithology in Shelby and Calhoun Counties, in Alabama. Although his nomenclature preceeded that of Hayes, the widespread use of the term "Rome" by the United States Geological Survey gave it preference. The term "Chocolocco Shale" was also given to Rome lithology in some publications of the Alabama Geological Survey (Butts, 1926). M. R. Campbell (1894, 1897) applied the name "Graysonton Formation" to Rome lithology in Pulaski and Montgomery Counties in Virginia, but in 1899 he coined the name "Russel Formation" for the same lithology in southwest Virginia, and so both of these terms were dropped. H. D. Campbell (1905) designated the Rome lithology the "Buena Vista Shale" from their exposure along the James River at Buena Vista in west - central Virginia but that term was soon abandoned. Stose (1906) applied the name "Waynesboro Formation" to the Rome lithology in Pennsylvania and southward to Roanoke, Virginia. This term is still in use and referred to as the northeast equivalent of the Rome Formation. Woodward (1929) considered the "Waynesboro" the stratigraphic equivalent of the Watauga Shale, and claimed that it is possible to trace the two formations into each other along their outcrops in the field.

The confusion surrounding the nomenclature of the Rome lithology was probably due to uncertainty concerning the age of the Rome, and to structural complexities within the Rome and the Appalachian Valley. Walcott (1886) illustrated this by assigning the "Knox Shale" of Safford to the Upper Cambrian, while the Knox Dolomite was considered Silurian in age. Although Walcott (1890) considered the Olenellus zone in the Rome to be of Early Cambrian age, he included the Rome lithology at Bays Mountain in the Upper Cambrian. Ulrich (1911) was not sure if the formations underlying the "Rome Sandstone" west of Chilhowee Mountain, namely 150 m (500 feet) of the "Beaver Limestone" and, beneath it, 455 m (1500 feet) of the "Apison Shale" are part of the Chilhowee Series or they are equivalent to the "Shady Limestone."

Butts (1926) reported that the term "Beaver Limestone" had been mistakenly applied to the "Shady Limestone" in Georgia and Alabama. He pointed out that the typical "Beaver Limestone" at Beaver Ridge, Tennessee was not the same as the "Shady Limestone," but was a younger formation. In this case the Beaver Limestone would be part of the Rome Formation. Butts (1926) estimated the thickness of the Rome in Alabama to be between 379 to 682 m (1250 to 2250 feet), and reported on some trilobite and brachiopod fossils in the formation from Rome of Alabama. In 1933, Butts described the Rome lithology in Virginia and reported that 75 percent of the formation was either red mudrock or green sericite shale, each in definite layers from 0.12 to 15 m (1 to 50 feet) thick. The remaining sandstone commonly occurs in thin beds, generally fine grained, and red, brown or green in color. He reported that sandstone beds are more abundant in the Rome in Tennessee than in the Rome of Virginia.

Butts (1940) gave a clear picture of the Rome in Virginia. He showed that the base of the formation is commonly marked by red shale, while the top is defined by the contact between the upper most clastic beds and the succeeding continuous sequence of Rutledge or Maryville Limestone, in Scott County, Honaker Dolomite farther northeast, or Elbrook Dolomite along the southeast side of the Appalachian Valley. Butts included the upper 60 to 180 m (200 to 600 feet) of the Rome type lithology in the Rome Formation although they contain Middle Cambrian fossils. He reported that the red shale is the most impressive feature of the formation throughout the Appalachian Valley from Pennsylvania to Alabama. He included a list of the characteristic fauna found in the Rome of Virginia indicating which of the fossils were Early or Middle Cambrian in age.

Woodward (1929) and Resser (1933, 1938) clarified the nomenclature of the Rome lithology and its equivalents in the Appalachians. They described the character of the Rome in the Appalachians and included characteristic fauna found in the Rome. Schuchert (1943) gave a general description of the Rome Formation and its equivalents in the Appalachians. Names applied to Rome lithology are summarized in Table 2.

Fox (1943) distinguished between the Rome and Rutledge formations at Watts Bar Dam. The Rutledge Formation comprised of uniformly calcareous sandstone is distinguished by the characteristic fossil Aneria bantius, while the Rome consisting mostly of brick red sandstone and shale with few calcareous units.

King et al. (1944) gave a detailed description of the Rome Formation and measured sections in northeast Tennessee and southwest Virginia. They reported the only complete Rome section at Valley Forge in Shady Valley,

Table 2. Names Applied to the Rome Lithology in the Appalachians.

Name	Location	Author	Year
Knox Sandstone	Tennessee	Safford	1869
Montevallo or Choccolocco Shale	Alabama	Smith	1890
Rome Formation	Georgia	Hayes	1891
Graysonton Formation	Virginia	M. R. Campbell	1894
Russel Formation	Virginia	M. R. Campbell	1899
Watauga Shale	N.E. Tennessee	Keith	1903
Buena Vista Shale	Virginia	H. D. Campbell	1905
Waynsboro Shale	Pennsylvania and Virginia	Stose	1906

with a thickness of 364 m (1200 feet), while an incomplete section at Damascus, Virginia measured 545 m (1800 feet). The Rome in northeast Tennessee is underlain by the Shady Dolomite and is overlain by the Honaker Dolomite. They reported also that one dolomite bed in the Rome could be traced for five miles in the same belt in Shady Valley. They recognized that the lower 23 to 30 m (75 to 100 feet) at the base of the Rome overlying the Shady Dolomite were transition beds composed of silty and shaly dolomite and dolomitic shale, with a massive blue gray dolomite bed near the middle.

Butts and Gildersleeve (1948) described the Rome Formation in Georgia as fully composed of sandstone and shale with rare thin layers of limestone. According to them, the lack of definite evidence of repetition in such well exposed sections as that east of Dalton, and that west of Oakman, suggest that the thickness of the Rome together with the Apison Shale is about 1515 m (5000 feet).

Harvey and Maher (1948) studied the lithologic and primary structural features of the Rome in the Valley and Ridge Province. They concluded that arenaceous and argillaceous sediments are more abundant in the western belts than in the eastern belts. Structural features associated with extremely shallow water and strand lines were found to be more abundant in the western belts. They suggested that the rain print horizon might be a good marker bed as it had been found in several localities. According to them, all the evidence, pointed toward a western provenance as a source for the detrital material.

Rodgers and Kent (1948) studied the section at Lee Valley in which 155 m (513 feet) of the Rome were measured and described. They reported the presence of an oolitic limestone horizon 53 m (177 feet) below the top of the formation. In that study they renamed the original "Rome Shale" of Hayes (1894a), the "Pumpkin Valley Shale". They concluded that the 109 m (360 feet) of shale overlying the Rome Formation in the Lee Valley section, constitutes a readily recognizable and mappable lithologic unit. Although this unit has commonly been included in the Rome, the lithology resembles that of the Conasauga and Nolichucky Shales, and bears a fauna indicating an early Middle Cambrian age more closely related to that of the overlying Rutledge Limestone. Rodgers (1953) defined the top of the Rome as extending downward from the highest prominent sandstone beds below the Conasauga Shale, while the base of the formation is usually concealed by faulting, except at Stony Creek (northeast Tennessee) where a complete section exists. According to him, the base of the Rome in northeast Tennessee is drawn beneath the lowest red shale, although yellow or black shale interbedded with massive dolomite may occur as much as 30 m (100 feet) lower.

Cattermole (1955, 58, 60, 66) mapped and described the Rome Formation in the Shooks Gap, Knoxville, Bearden and Fountain City quadrangles. He reported that the Rome in Shooks Gap is about 455 m (1,500 feet) thick, and that it is in conformable contact with the Shady Dolomite. Recent USGS maps do not show such contact but instead show the base of the Rome cut by the Dumplin Valley Fault (Swingle, 1966).

Brooks (1955) studied halite crystal casts found on the lower bedding plane of fine-grained sandstones in the Rome Formation at War Ridge, Grainger County, Tennessee. He concluded that the crystal imprints in the argillaceous sediments probably formed in small pools on mud flats.

He pointed out that this is not necessarily an indication of supersalinity in the Rome Sea or proof of an arid climate.

Bridge (1956) described the Rome in the Mascot - Jefferson City district as consisting largely of thick rusty sandstones below and arenaceous varicolored shales above. Yellow, orange and maroon tones are prominent in the shale, but the highest beds are mostly greenish which appear to correspond to the Pumpkin Valley Shale. He estimated the thickness of the Rome in that area to be around 303 m (1000 feet). King and Ferguson (1960) reported that most of the iron and manganese deposits in the Rome Formation occur in the residuum of the thick dolomite beds. They indicated that the contacts of the Rome with the underlying Shady Dolomite and the overlying Honaker Dolomite are gradational.

Woodward (1961) basing his study of the southeastern Appalachian interior plateau on 160 deep wells, found tremendous thickness of the Rome in the subsurface of Virginia. He suggested that the Rome sediments were deposited in a delta or fan-like deposition. Spigai (1963) did a Master's thesis on the Rome Formation. His work consisted of detailed examination of three exposures in the Valley and Ridge Province in Tennessee. The sections he measured are at Beaver Ridge, Knox County, Log Mountain, Grainger County and Dug Ridge, Roane County. He included a detailed description of primary structures found in the Rome, a grain size analysis, and also analyzed the iron oxide and heavy mineral content. He was not able to find any marker beds in the sections he studied.

Swingle (1960a, 60b, 60c, 64a, 64b, 64c, 67a, 67b) mapped the Rome in several localities in East Tennessee. He described the formation as consisting of shale, siltstone and sandstone with beds of gray limestone near the base. The shale is described as variegated, reddish and greenish, micaceous and generally arenaceous. Siltstone layers as much as a few inches thick are medium gray, in part glauconitic. The sandstone beds are generally fine-grained, thin to medium bedded and as much as 0.60 m (2 feet) thick. He reported that the formation is characterized by an abundance of ripple marks, mud cracks, and irregularly oriented bedding plane markings. He estimated the thickness of the Rome in the Evensville quadrangle to be around 303 m (1000 feet). Finlayson (1964a, 64b, 65) mapped the Rome Formation in Tennessee in the Maynardville, White Hollow and Joppa quadrangles. His description of the Rome lithology is similar to that of Swingle. He estimated the thickness of the formation in those areas to be around 303 m (1000 feet).

Harris (1964) based on the study of Rome cores in central Kentucky and Conasauga and Rome exposures in northeastern Tennessee, concluded that sandstone of the Rome in central Kentucky is by lateral gradation a facies equivalent of approximately the lower half of the Conasauga Group of northeastern Tennessee. He claimed that the Rome probably ranges in age from Early Cambrian in eastern Tennessee to Middle Cambrian in Central Kentucky. Palmer (1970) gave a brief description of the Rome lithology, its association with thrust faults, estimated thickness and depositional environment in the Appalachian Valley. He followed the conclusion of others that the Rome is of Early Cambrian age depending on the presence of olenellid trilobites.

Mixon and Harris (1971) mapped the Rome on the Swan Island quadrangle, describing the lithology as consisting mainly of shale, siltstone, and sandstone, with 18 m (60 feet) of medium bedded, dark-gray dolomite close to bottom. They reported that the exposed thickness in that area is between 115 to 182 m (380 to 600 feet). McLaughlin (1973) dealing with the biostratigraphy and stratigraphy of Knox County and vicinity, reported that trilobites of Cambrian age in the Appalachian Valley, when compared with known ranges of some restricted Cambrian genera appear to be at variance with the interpretation of the sedimentary units identified with the collection site. He believes that

> . . . . parts of the Shady, Rome and Conasauga are time related across the lower to Upper Cambrian [at least to Dresbachian] stratigraphic interval. . . . The inter-relationship of the Pumpkin Valley Shale with the Rome below and the Rutledge and Nolichucky formations above can be established on biostratigraphic evidence through mutual sharing of alokistocarid trilobites and because the range of the genus Solenopleurella is confined to Middle Cambrian.

As to the age of the Rome Formation, McLaughlin stated that,

> . . . . to treat the Rome Formation as exclusively Early Cambrian in age requires extending the Middle Cambrian ranges of three orders of trilobites, well established on a worldwide basis. On the other hand, to regard the Rome as entirely Middle Cambrian in age would amount to an even more unlikely extension of the range of Olenellus, and another Rome associate from Virginia to Alabama, Archaeocyathus, fixed in Early Cambrian time the world over.

CHAPTER II

MATERIALS AND TECHNIQUES

Introduction

In order to study the lithology, facies relationships and environments of deposition of the Rome Formation, thirteen stratigraphic sections were studied along and across the strike of the Rome ridges. Gaps and road cuts across those ridges determined the location of the outcrops which are fairly equally spaced along strike (Figure 5, page 10).

Field Analysis

The vertical extent of the Rome Formation at each outcrop was determined by locating the bottom of the formation, marked by a thrust fault, and the upper contact with the Pumpkin Valley Shale, marked by the highest prominent sandstone bed below the Conasauga Shale (Rodgers and Kent, 1948). In eight of the thirteen sections the Rome - Pumpkin Valley contact was exposed, but in the remainder the top of the Rome is covered. Each measured section was divided into rock-units which were marked with paint and then numbered from the bottom upwards. A unit is defined here as one bed or several beds which have distinctive characteristics such as color, lithology, texture and bed thickness that distinguish it from the sequences immediately above and below. Units were designed to aid in correlation of the Rome parallel to and across strike. Some units were designated as oolite or Skolithos zones because those features are prominent in the Rome Formation, and are not repeated within the same section. The units were measured with a 200 inch steel tape. The

Geological Society of America Rock Color Chart (1963) was used to describe the fresh and weathered rock surface colors. Grain size was determined in the field by using a 10X hand lens and the grade scale (Table 3) which is a modification of the Wentworth Scale. Bedding thickness terminology (Table 4) is a modification of the bedding thickness classifications of McKee and Weir (1953) and Ingram (1954). The terms flaser, lenticular and wavy bedding follow the definitions of Reineck and Wunderlich (1968). Additional bedding terms are included in the Appendix.

Sampling Methods

About 300 terrigenous clastic and carbonate rock samples were collected from the Rome sections. Most of the samples were taken from the following exposures: Pine Ridge I-75, Diggs Gap, Crippen Gap, Sharp Gap and Shooks Gap. Units from which samples were taken are marked with an asterisk in the Appendix. Due to the large number of units in the stratigraphic sections, samples were collected selectively to aid in the correlation and interpretation of the environments of deposition. Units which contain sedimentary structures and trace fossils were sampled for this purpose. Each sample was coded in a progressive sequence and the stratigraphic up direction was marked before removing the sample from the outcrop. Of the 300 samples, 190 were thin sectioned and about 20 were slabbed and polished. This was done by eliminating those samples which appeared to be repetitious of stratigraphically adjacent thin sections. Rock samples containing biogenic and sedimentary structures were collected and the structures described and identified. About 50 of these samples have been donated to the Department of Geological Sciences, University of Tennessee.

Table 3. Relative scale of grain size terminology.

Term	Diameter in mm.
Granule to boulder	2+
Very Coarse	1 - 2
Coarse	1/2 - 1
Medium	1/4 - 1/2
Fine	1/8 - 1/4
Very fine[1]	1/16 - 1/8
Silt[2]	1/256 - 1/16
Clay[3]	1/256 and less

[1]Individual grains just visible to the naked eye.

[2]Individual grains distinguished under 10X magnification.

[3]Individual grains not distinguished under 10X magnification.

Table 4. Relative scale of bedding terminology.

Term	Thickness in Metric Units
Massive	+ 180 cm.
Very thick bedded	120 - 180 cm.
Thick bedded	60 - 120 cm.
Medium bedded	15 - 60 cm.
Thin bedded	5 - 15 cm.
Very thin bedded	1 - 5 cm.
Laminated	2 mm. - 1 cm.
Thinly laminated	Less than 2 mm.

Microscopic Investigations

Petrographic examinations of thin sections were made to supplement field data, and to recognize any features which cannot be seen in the field. Features such as texture, mineralogy, matrix or cement, sedimentary structures, diagenetic effects and fauna were studied; these features will be described and discussed in the chapter on lithology. Micrometer measures of grain sizes were made using the Wentworth Scale, while Powers' Scale of roundness (1953) was used to determine roundness of grains. Sorting was determined by the visual reference of Compton (1962), while the charts for estimating percentage composition of rocks and sediments of Terry and Chilingar (1955) helped in estimating percentages. Folk's carbonate terminology (1962) was used to describe carbonate samples. The thin section descriptions and field observations served as the basis for interpretation of environments of deposition, diagenetic effects and facies relationships within the Rome.

CHAPTER III

LITHOLOGY OF THE ROME FORMATION

General Characteristics

The Rome Formation is composed predominantly of sandstone and shale with occasional beds of gray limestone and dolomite. The color of sandstone is variable with the most common colors being grayish red, light brownish gray, and greenish gray. They are mostly very fine-grained with occasional very thin to thin bedded, coarse to very coarse-grained sandstone. Sandstone beds are typically laminated, very thin to medium bedded, and rarely are they thick bedded. Many of the thin to medium bedded sandstones wedge out in short distances. Glauconitic laminae are usually common in sandstone beds.

Shale is variegated reddish and greenish, micaceous and generally arenaceus. Units consisting solely of shale are rare because the shales are typically interlaminated with sandstone. Siltstone layers as much as several centimeters thick are grayish red to greenish gray and in part glauconitic. The limestone and dolomite beds are generally dark to medium gray in color, medium to thick bedded, silty or sandy with abundant sandstone and siltstone lenticles.

The proportions of the above lithologies vary greatly along and across the strike in East Tennessee. Sandstone and siltstone beds make up 65 to 80 percent of the Rome section in western belts of the Appalachain Valley. This proportion decreases to 48 percent at Bays Mountain and 8 percent in northeast Tennessee. Shales make up a maximum of 33 percent in western belts but this percentage increases to about 70 percent in northeast Tennessee. Limestones in the Rome make up about 10 percent of the carbonate rocks while the rest is dolomite. Carbonates in the western part of the valley make up only 12 percent of the Rome section but are dominant at Bays Mountain where they constitute 40 percent of the section. Thus, there is a general increase in the proportion of shale and carbonates southeastward, while sandstones and siltstones increase in proportion northwestward.

To the south in Georgia Resser (1938) described the Rome as a very heterogeneous formation which is distinguished by its red shale. It consists of shale, sandstone, calcareous and argillaceous beds, dolomite and pure blue limestone. To the northeast in Virginia Butts (1940) reported similar characteristics and indicated that red shale is the most conspicuous feature of the Rome Formation throughout Virginia. Both of the above authors point out that the proportion of the various lithologies within the formation vary parallel to and across strike.

Characteristic Colors

The variety of colors in the Rome Formation is one of its most characteristic features, with reddish, maroon, purple, brownish and greenish colors predominating. Terrigenous clastic units do not show much change in color on weathering, but carbonates show a large difference between primary and weathering colors. Red and maroon colors are dominant in any Rome exposure, but where thick carbonate units or their weathered products are present, brownish yellow or light orange colors are common. As mentioned earlier, red, brown and green colors characterize the Rome Formation in Tennessee, Georgia and Virginia. Thus the Rome can be recognized by these colors throughout the Valley and Ridge Province.

Red beds in the area of investigation are dominant at the bottom and middle of the Rome sections. The grayish red sandstones and shales grade upward and alternate with light brownish gray and greenish gray sandstone and shale. In most sections red beds become rare to absent upwards (Sharp Gap, Plate 4).

The red color of shales and sandstones is due to the presence of disseminated iron oxide which forms the matrix and cement in red sandstones. The limonitic colors in some glauconitic sandstones could be attributed to the alteration of glauconite into limonite. The dark greenish gray colors in sandstone are due to the high percentage of glauconite in the rock, while the greenish gray color in shales and in some sandstones is more commonly due to the presence of chlorite. The fresh color of carbonates is dark to light gray due to the common content of carbonaceous material and clay impurities. These carbonates weather to brownish or light orange, but when deeply weathered they become a dark yellowish orange silty clay.

Bedding Characteristics

Bedding types in the Rome Formation range from thinly laminated shales to massive dolomites and limestones. King et al. (1944) reported that shaly dolomite beds in northeast Tennessee are generally less than 60 cm (2 feet) thick, but units of massive blue-gray dolomite 4.5 to 30 m (15 to 100 feet) thick are present. The thinner shale, siltstone and dolomite beds of the Rome are probably lenticular, but the thicker siltstone and dolomite beds may have great lateral extent. According to King et al. one dolomite bed was traced 8 km (5 miles) parallel to strike. Butts

(1940) indicated that dolomite beds in the Rome of Virginia reach a thickness of 15 to 30 m (50 - 100 feet) while sandstone and siltstone beds are much thinner. In Georgia, Resser (1938) described the Rome as being made up of red mudrock or green shale, each in discrete layers from 0.30 to 15 m (1 to 50 feet) thick. The dolomite and limestone units may individually reach a thickness of 15 m (50 feet).

The thickness of individual beds in the area of investigation ranges from thinly laminated to very thick bedded. Thinly laminated to thin bedded layers, that is beds with a thickness of less than 2 mm to 15 cm, make up 75 percent of the Rome Formation, medium bedded layers, about 15 percent, and the remainder, about 10 percent, is made up of thick to very thick bedded layers. Shale layers are usually thinly laminated, but where they are silty or sandy, they are laminated to very thin bedded. Sandstone beds are mainly laminated to thin bedded with common medium bedded layers, while thick to very thick bedded sandstone layers are rare. Carbonates interbedded with sandstone and shale are thin to medium bedded, but where large units of dolomite and limestone are present, individual beds are thick to very thick bedded (Pine Ridge I-75 and Porterfield Gap Plates 1 and 5).

Interlaminated shales and sandstones are dominant throughout the Rome Formation in the study area. Within these interlaminated layers, flaser and lenticular bedding is common. Lenticular bedding is also seen in dolomites which have siltstone and sandstone lenticles which are discontinuous vertically and horizontally (Figure 6). Thin to medium bedded sandstone layers generally wedge out in a distance of several meters, to be replaced laterally by several thin or laminated beds. Thus, these thin

Figure 6. Lenticles of siltstone and very fine grained sandstone in darker dolomite beds at Pine Ridge I-75. Scale is 15 cm. long.

to medium bedded layers are of limited lateral extent, but the thick bedded sandstone layers at the top of the Rome section at Bullrun Ridge were traced from Diggs Gap to Pumphouse Road section, a distance of 20 km (Plate 2).

IV. THIN SECTION DESCRIPTION

Introduction

The purpose of thin section study is to complement field investigation, aid in stratigraphic correlation and interpretation of environments of deposition. Thin sections were intended to reveal gross mineral composition, grain size, roundness grades, degree of sorting, proportion of clay-size particles in matrix, diagenetic features, primary sedimentary and organic structures.

Of the 190 thin sections prepared, 105 are sandstone, 9 siltstone and 6 conglomerate, while 70 are carbonates which are mainly dolomite or dolomitic limestone. Although carbonates make up about 10 percent of the Rome Formation, the number of carbonate samples investigated represent more than 35 percent of the samples. This was intended, because carbonates forming within the basin of deposition are better environmental indicators than clastic rocks made up of transported sediments.

Volume percentages of each of the constituents noted in each sample were determined by using Terry and Chilingar (1955) charts for estimating percentage composition. About ten measurements were made of every thin section, and the maximum, minimum and/or average are reported here. Powers' (1953) scale of roundness was used to determine roundness grades; the dominant grade, associated grain size and percentage were noted. Sorting was determined by the visual scale of Compton (1962) and by determining the number of size classes in each thin section. No attempt was made to study clay mineralogy or clay size matrix constituents in the rocks of the Rome. These are beyond the scope of this study, which is designed mainly to correlate the stratigraphy and determine environments of deposition on other basis.

Sandstone

Grain size. The dominant grain size in the Rome Formation is very fine. In 80 percent of the thin sections the fine grain size is predominant. In fact, many of the Rome sandstones in the study area referred to as siltstone in the lieterature are very fine-grained sandstone. Medium grained sandstones are rare and make up less than 6 percent of the samples, while coarse to very coarse grained sandstones constitute less than 8 percent. The matrix of fine sandstones is made up of very fine siltstone and clay, both of which constitute less than 15 percent of the volume of the samples. Poorly sorted sandstones have a higher percentage of very fine siltstone and clay in the matrix with a maximum of 30 percent The matrix of coarse, well sorted clean sandstones is made up of silica cement.

Texture. Individual grains in very fine to fine sandstones are predominantly angular in shape, but roundness increases with increasing grain size. The medium and coarse-grained sandstones are subangular to well rounded with more than 50 percent of the grains in the subrounded to rounded range. The fine sandstones without exception are well sorted. The coarse sandstones (7 percent) are also well sorted (Figure 7) with

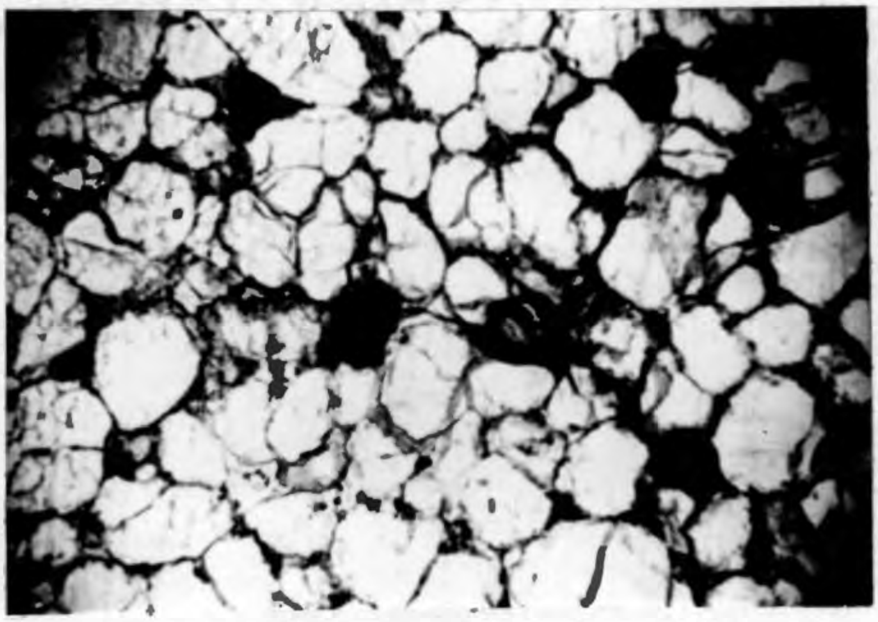

Figure 7. Photomicrograph of well sorted coarse grained sandstone, from Pine Ridge I-75, unit 131, transmitted light, 10X.

two samples moderately sorted. Fifteen samples out of 105 are poorly sorted. In these samples the coarse grains constitute a maximum of up to 30 percent, but in all of these samples fine-grained particles make up more than 30 percent of the sample (Figure 8).

Mineralogy. Quartz is the most abundant mineral in sandstones, with some clean sandstones entirely made up of this mineral. The percentage of quartz drops to 60 percent in some glauconitic sandstones, but the typical Rome sandstone in the area of investigation contains more than 80 percent quartz.

Glauconite is found in 55 percent of the sandstone samples studied. It constitutes up to 40 percent in some dark greenish gray sandstones, but in 80 percent of the glauconitic sandstones, glauconite makes up 1 to 15 percent of the sandstone. Glauconite is usually concentrated in laminae; the size of individual grains being equal to, or one size class larger than quartz grains with which they are interlaminated. Fine to coarse glauconite grains are typically subrounded to well rounded with coarse grains showing a darker green color. In thin section, dark green glauconite pellets exhibit partial alteration to limonite, by the presence of a brownish limonitic halo surrounding the dark green center.

Iron oxide, which gives the sandstones of the Rome their red color, is found as disseminated very fine grains and coatings on quartz grains and clay size particles in the matrix. Iron oxide is usually concentrated in laminae (Figure 9) indicating that it was transported. In 50 percent of the sandstone samples, iron oxide content ranges from 3 to 15 percent to a maximum of 30 percent in some samples.

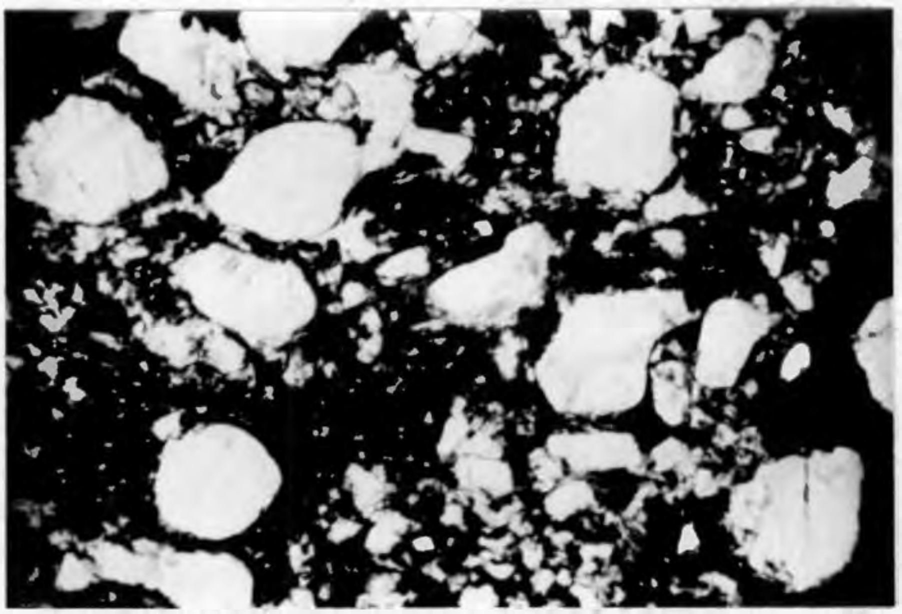

Figure 8. Photomicrograph of poorly sorted sandstone with iron oxide matrix, Sharp Gap, unit 11, transmitted light, 10X.

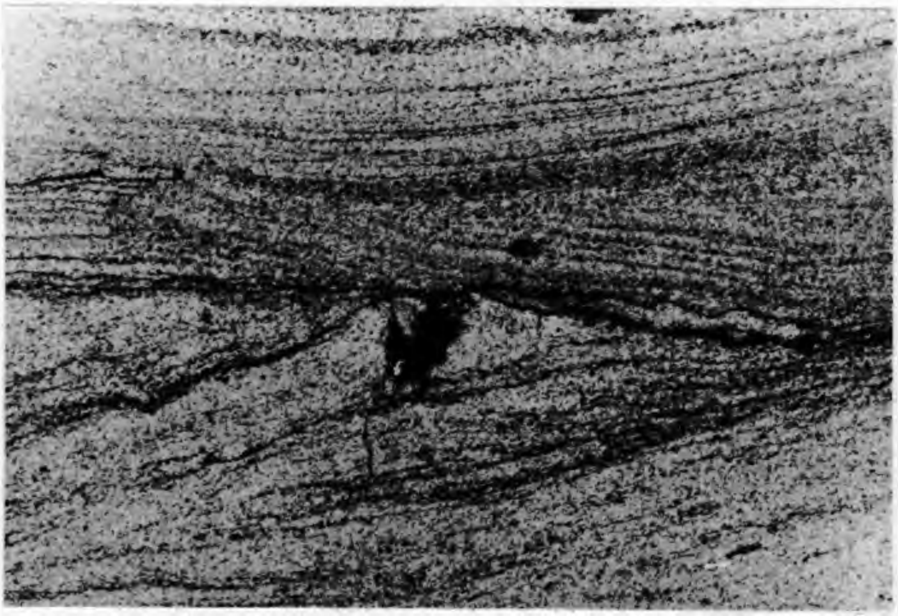

Figure 9. Photomicrograph of iron oxide concentrated in laminae, with a burrow in the center filled with iron oxide, Sharp Gap, unit 10, transmitted light, 4X.

Feldspar grains with albite and polysynthetic twinning were found in 40 percent of the samples in very fine-grained sandstone. The randomly distributed feldspar grains are very fine, angular and, in all cases, make up less than 1 percent of the sample.

Heavy minerals, primarily zircon, biotite and garnet are rare; they were seen in only twelve samples out of 105, in very fine-grained sandstone. Very fine grains of garnet and abraided euhedral crystals of zircon were found to comprise less than 1 percent of each sample. Brownish biotite lamellae (0.3 mm long) parallel to laminae, make up 1 to 3 percent of the samples in which they are found.

Hematitic granules and pebbles are comprised of very fine to coarse angular grains of quartz cemented by hematite. These grains are black, but in thin section many of them look brownish red. The hematite content in these granules ranges from 30 to 90 percent. The granules are rounded to well rounded indicating that they were transported. Some of the pebbles are up to 3 cm long, and some show micro-cross-laminae (Figure 10). These granules were seen in 10 percent of the sandstone samples and make up from less than 1 to 40 percent. Generally the granules are more common in conglomerates.

Sedimentary structures. Many of the sandstone beds which look featureless exhibit current laminations and micro cross-laminations in thin section. Current lamination produced as a result of alternate deposition of glauconite and sand, or iron oxide and sand, were seen in 40 percent of the 105 sandstone samples, while micro cross-laminae in 10 percent of the thin sections. Small scale scour and fill structures were observed

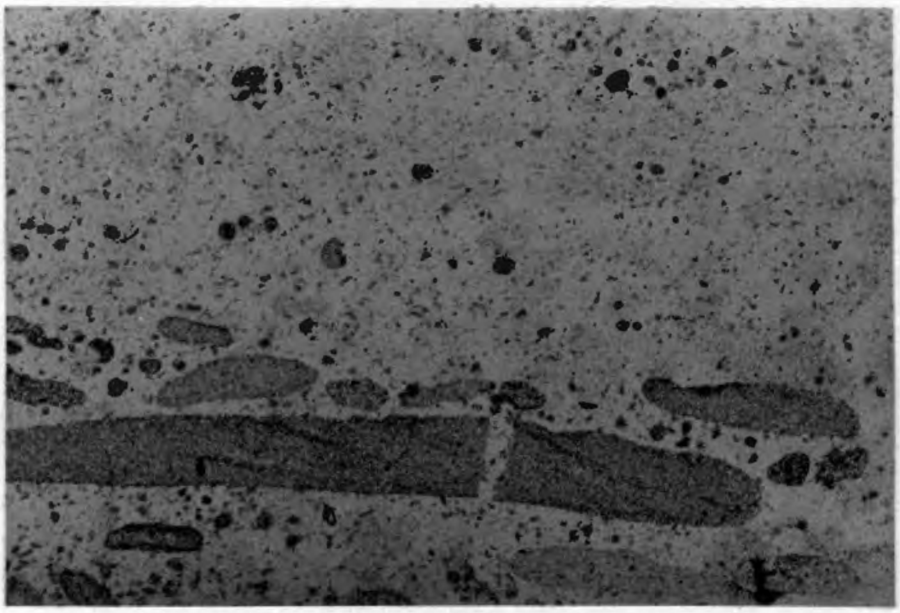

Figure 10. Photomicrograph of hematitic pebbles and granules showing micro cross laminae in large pebbles at the bottom in a matrix of very fine-grained sandstone, Young Creek, unit 30, transmitted light, 4X.

in 3 percent of the thin sections studied. The above structures are found in grayish red and greenish gray sandstones.

Biogenic structures. Burrows and bioturbation are the only evidence of organic life in the sandstone thin sections. The burrows, up to 0.5 cm wide and up to 1.5 cm long, are usually filled with silt or iron oxide. They occur in both grayish red and greenish gray very fine-grained sandstone. In bioturbated samples the laminae are irregular and disturbed (Figure 11). Only 10 percent of the sandstone samples examined have burrows, and in most of those samples the burrows are not abundant.

Siltstone

In the nine siltstone thin sections prepared, quartz is the most abundant mineral. The grayish red and grayish orange clay matrix constitutes less than 20 percent in seven thin sections. In the remaining two samples the matrix is made up of dolomite which constitutes 15 and 50 percent of the samples respectively. The content of glauconite found in four thin sections ranges between 3 to 15 percent, while hematite content ranges between 10 to 30 percent in four samples. Current lamination is more common than cross lamination, the former was found in five samples while the latter in one sample only.

Conglomerate

Conglomerate is defined here as any clastic sedimentary rock which has 10 percent or more rounded grains of greater than 2 mm in diameter (Pettijohn, 1949). Only six samples observed fall in this category; in

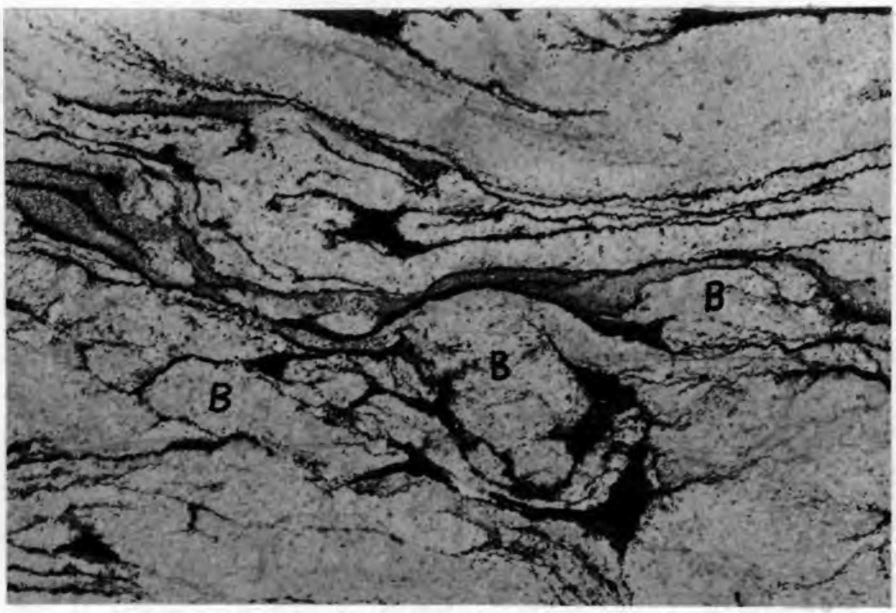

Figure 11. Photomicrograph of burrows (B) disturbing very fine-grained sandstone laminae, the dark material is probably carbonaceous matter, Nelson Branch, unit 16, transmitted light, 4X.

fact, conglomerates make up less than 1 percent of the Rome section, where they are found in thin to very thin beds. Grain sizes in the conglomerates matrix range from very fine to very coarse grained sandstone. Hematitic granules and pebbles are common clasts, constituting up to 30 percent in some samples, but at Crippen Gap unit 25, hematite granules and pebbles are intermixed with dolomite intraclasts (Figure 12).

Carbonate Rocks

Introduction

Carbonate rocks in the Rome Formation according to the classification of Folk (1962) fall into six main categories. In order of decreasing abundance these are: finely to coarsely crystalline dolostone, intrasparite, pelsparite, oosparite, dolomicrite and biosparite. More than 83 percent of the carbonates are made up of microsparite and very fine to coarse sparite, while micrite, found in 17 percent of the samples, comprises less than 10 percent of the rock. In two samples only, micrite content reaches 30 and 60 percent respectively. As mentioned earlier the carbonates in the Rome are not pure; siltstone is common in dolostones as well as limestones. Allochems are common, the most abundant being intraclasts. Pellets, ooids and fossils follow in decreasing abundance.

Intraclasts

Intraclasts were found in 17 percent of the samples studied; they constitute 5 to 70 percent of the rock. Intraclasts composed of microsparite and very fine sparite, are more common in limestones than dolostones. They range in size from less than 1 mm to 3 cm in length. Most are rounded to

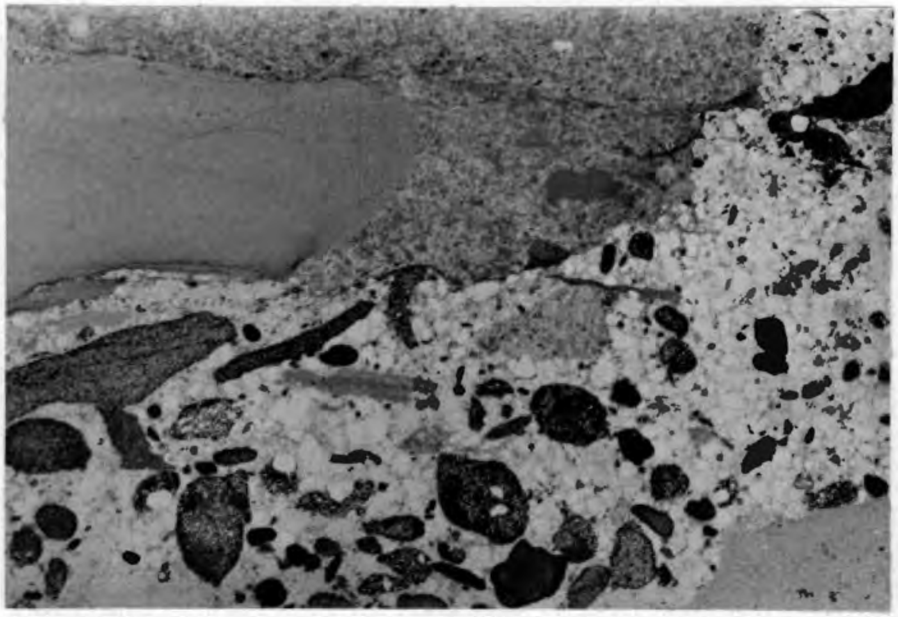

Figure 12. Photomicrograph of hematitic granules and pebbles (black) in a matrix of very fine-to coarse-grained sandstone (white); large dolomite intraclasts at the top (gray), Crippen Gap, unit 25, transmitted light, 4X.

well rounded with the large intraclasts showing current laminations. Many of these intraclasts show a dark rind or coating on the outside which is probably algal in origin.

Pellets

Well rounded to oblate pellets up to 0.15 mm in diameter are concentrated in laminae which alternate with siltstone or micritic laminae. Pellets were found in 17 percent of the samples and constitute 3 to 70 percent of the rock. The absence of fossils or burrows makes it difficult to determine their origin, since some pellets might be intraclastic in origin (Folk, 1962).

Oolites

Oolites are found close to the top of the Rome (Plates 1, 4 and 5) in the following localities: Pine Ridge I-75, Oak Ridge, Young Creek, Sharp Gap, Shooks Gap and Porterfield Gap. Samples were taken at each locality.

In all of the above sections the oolites are dolomitized except at Young Creek. Mature and well sorted ooids resembling the Bahaman type ooids are found at Pine Ridge I-75 and Oak Ridge. Ooids at these two sections are up to 2 mm in diameter, and show concentric laminae. Where the nuclei of ooids are not recrystalized, they are clearly micritic. Ten percent of the nuclei consist of very fine grained glauconite. Glauconite pellets found in the matrix, are fine to medium grained, well rounded and make up less than 25 percent of the rock.

In the above two sections ooids make up more than 60 percent of the rock. In the other sections ooids are not as mature and do not exceed

0.9 mm in diameter. Glauconite constitutes less than 10 percent of these rocks, and in the oolites at Sharp Gap glauconite is completely absent.

Fossils

Body fossils are rare in the Rome Formation and in the area of investigation are confined to carbonate rocks. The fossil fragments recognized are those of trilobites, brachiopods and echinoderms. Only 10 percent of the carbonate samples examined contain fossils and in those, fossils constitute less than 5 percent of the rock. The most abundant fragments are trilobites, with brachiopods up to 1 percent and echinoderm fragments less than 1 percent of the entire rock sample. Fossil fragments make up more than 30 percent of the rock in a 3 cm thick limestone horizon (PR unit 118). In this horizon trilobite fragments (30 percent) are the most abundant, brachiopods up to 3 percent and echinoderm fragments less than 1 percent, intraclasts less than 20 percent, superficial ooids about 2 percent, while the rest of the rock is made up of sparry calcite matrix (Figure 13).

Lithoclasts

Quartz siltstone is the most abundant terrigenous clastic material in the carbonate rocks. It is found in 65 percent of the samples. It constitutes 3 to 40 percent of the carbonate samples with an average of 15 percent. Siltstone is usually concentrated in laminated lenticles, some of which show graded bedding (Figure 14). Medium to coarse quartz sand grains are rare in carbonates, and, constitute less than 1 percent in oolites.

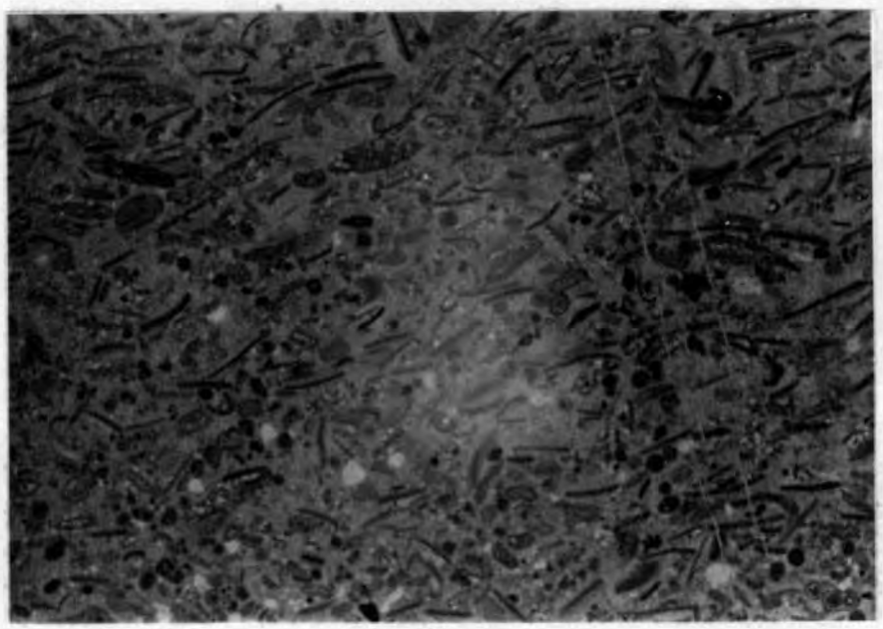

Figure 13. Photomicrograph of biosparite showing long trilobite fragments, subrounded intraclasts (gray) and superficial ooids in a sparry calcite matrix, Pine Ridge I-75, unit 118, transmitted light, 10X.

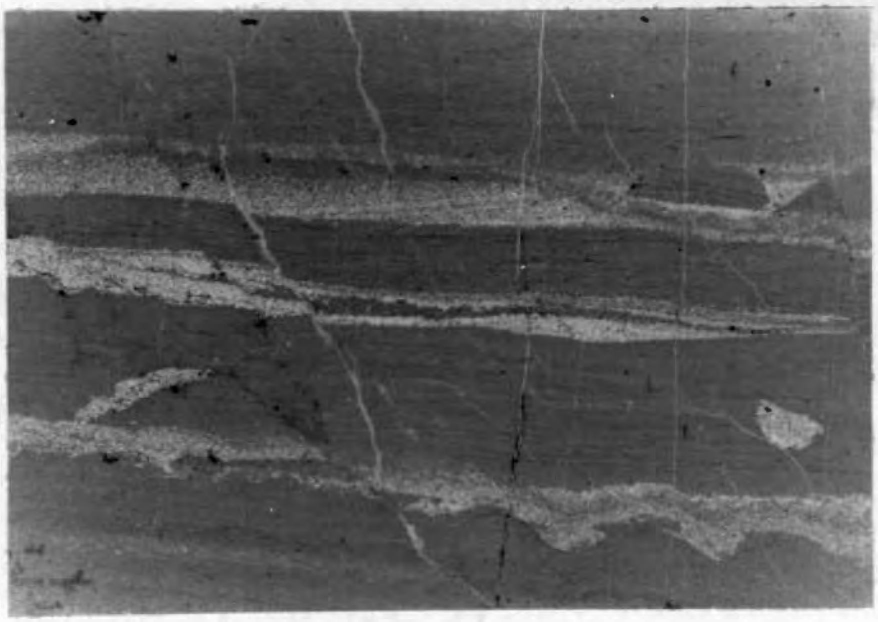

Figure 14. Photomicrograph of siltstone lenticles in current laminated dolomite, Nelson Branch, unit 17, transmitted light, 4X.

Glauconite

Glauconite is not confined to terrigenous clastic rocks, it occurs in carbonates as well, but in less abundance. Observed in 30 percent of the samples, it constitutes 1 to 25 percent of the rock. Of all carbonate samples observed glauconite is most abundant in the oolite samples with a maximum of 10 percent in nonoolitic rocks. The glauconite pellets in the matrix of oolites are fine to medium grained, subrounded to well rounded showing the effect of transportation, while in other carbonates they are very fine to fine grained subangular to subrounded.

Sedimentary Structures

Sedimentary structures similar to those in terrigenous clastics were observed also in carbonates. Current laminations, found in 28 percent of the samples, resulted from the alternate deposition of silt and carbonates or pellets and micrite. Micro cross-laminae and graded bedding were observed in 10 percent of the thin sections. Birdseye structures up to 3 mm in diameter were observed in two carbonate samples only. They are arranged in a horizontal plane and associated with algal laminae (for further explanation see Chapter IV on Sedimentary Structures). Dark, wavy, crinkly laminae up to 0.1 mm thick observed in 24 percent of the carbonate samples are probably algal in origin.

Biogenic Structures

Like the sandstones, burrows and bioturbation were observed in 10 percent of the carbonate samples. In all the samples examined, the burrows are full of silt and usually connect two silt laminae. Most of the burrows are less than 0.5 cm wide and more than 1 cm long (Figure 15). A large conspicuous burrow in dolomite from Pine Ridge I-75 unit 86 is 1.5 cm wide and 3.5 cm long, in which the laminae are disturbed and mixed up within the burrow (Figure 16). There is no evidence in the sample to indicate what kind of organism produced such a burrow.

Diagenesis

Since more than 83 percent of the carbonate samples are made up of sparite, it is clear that the carbonates were altered by diagenesis. This is clearly seen in unit 90 at Pine Ridge I-75, where the dolomitic limestone is made up of coarse sparry dolomite (50 percent) and intraclastic microsparry calcite (Figure 17). The oosparite, intrasparite and pelsparite rocks in the Rome show evidence of diagenesis with microsparite in ooids and intraclasts, while very fine to coarse sparry calcite and dolomite make up the matrix of these rocks (Figure 18). In many diagenetic dolomites it is difficult to determine what the original lithology and texture were before diagenesis, thus interpretation of their environments of deposition is rather difficult.

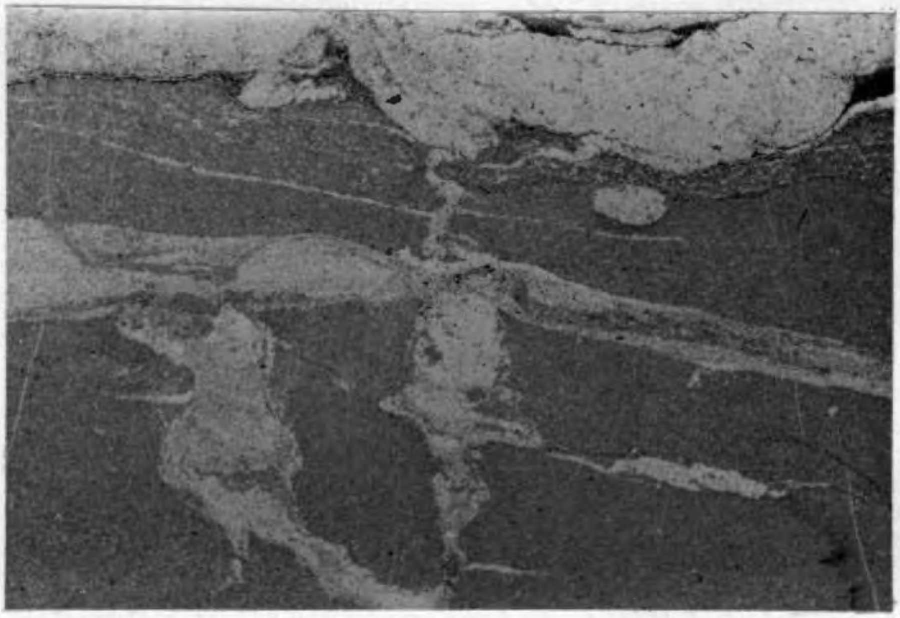

Figure 15. Photomicrography of burrows filled with siltstone (white) pelmicritic dolomite (gray), Nelson Branch, unit 16, transmitted light, 4X.

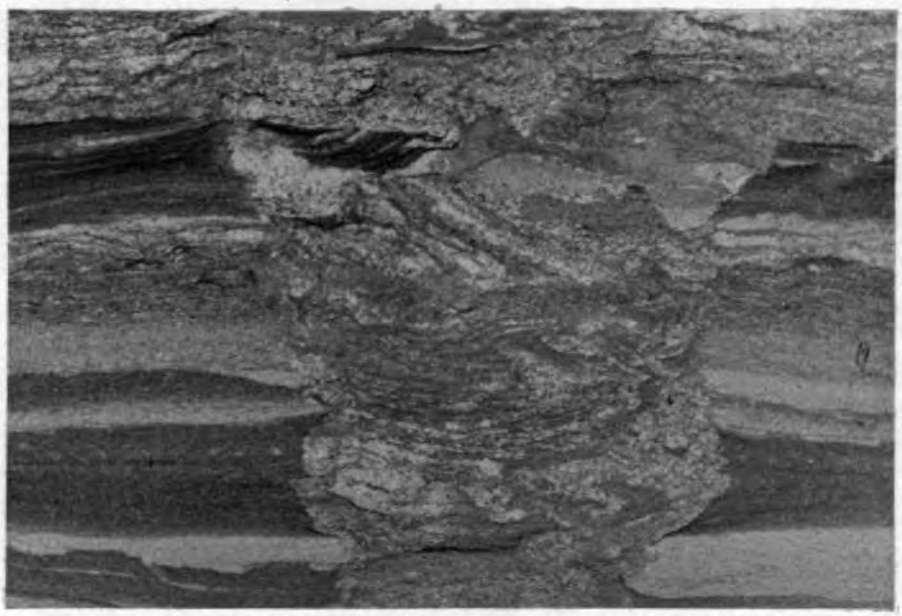

Figure 16. Photomicrography of disturbed laminae inside a burrow in laminated dolomite, Pine Ridge I-75, unit 86, transmitted light, 4X.

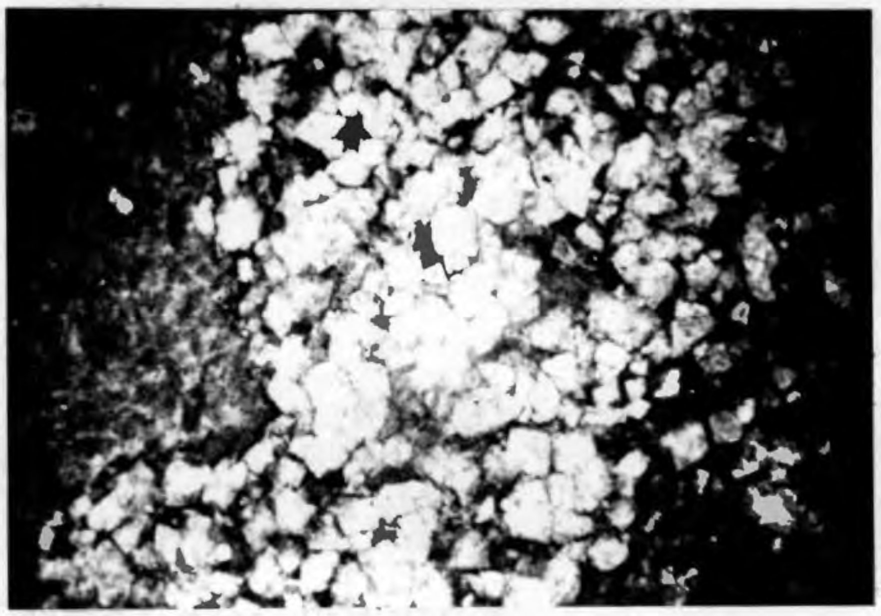

Figure 17. Photomicrograph of dolomitic limestone, intrasparry limestone (dark) replaced by well crystallized dolomite (white), Pine Ridge I-75, unit 90, transmitted light, 25X.

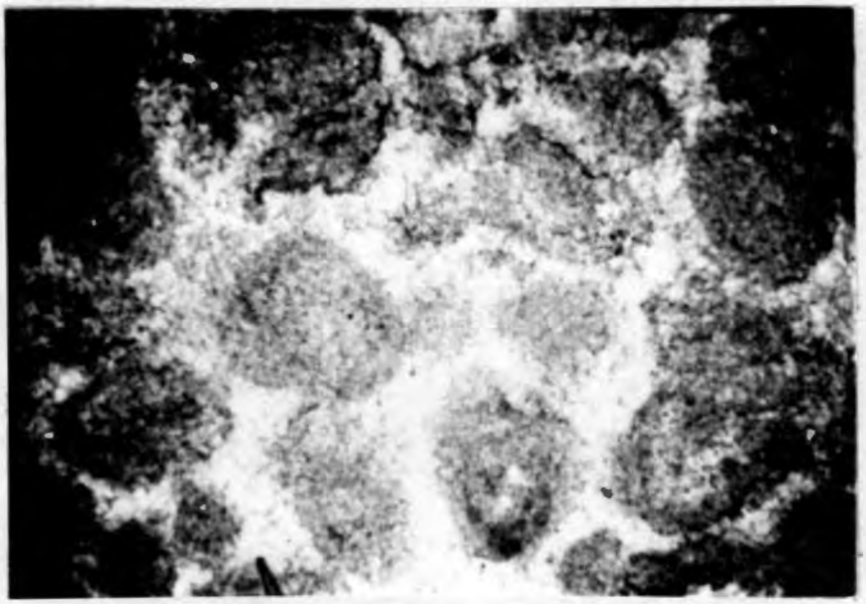

Figure 18. Photomicrograph of diagenesis in oolites, very fine sparry dolomite in ooids, coarse sparry dolomite in matrix, Sharp Gap, unit 8, transmitted light, 25X.

CHAPTER IV

INORGANIC SEDIMENTARY STRUCTURES

I. INTRODUCTION

Besides its maroon color, the second most characteristic feature of the Rome Formation is the abundance of sedimentary structures most of which indicate deposition in a tidal flat environment. The following structures were recognized in the Rome: mud cracks, halite crystal casts, ripple marks, rain prints, tidal balls, cross-bedding, ripple laminae, current lamination, scour and fill, flute and groove casts, load casts, vugs, birdseyes and flaser and lenticular bedding. The last two structures are described in the chapter on environments of deposition.

II. MUD CRACKS

Mud cracks form as sediments lose contained water. The cracks bound polygons which vary in number of sides. Cracks are rarely straight and range in width from a few millimeters to 2 cm. Polygons in the Rome Fromation may be bounded by as few as three and as many as six sides. The polygons range in diameter from a few centimeters to more than 30 cm (Figures 19 and 20). Mud crack polygons and mud crack fillings have been reported from most of the Rome exposures in the study area (Plates 1 - 5). There is a strong correlation between red beds and mud cracks, although they are not confined to red beds, they are found in less abundance in some dolomite beds (Appendix PR unit 86, PG Unit 17) and light greenish gray sandstone (Appendix PH unit 26). The crack filling in red beds is grayish

Figure 19. Large mud crack polygons, Porterfield Gap, unit 63, scale 15 cm. long.

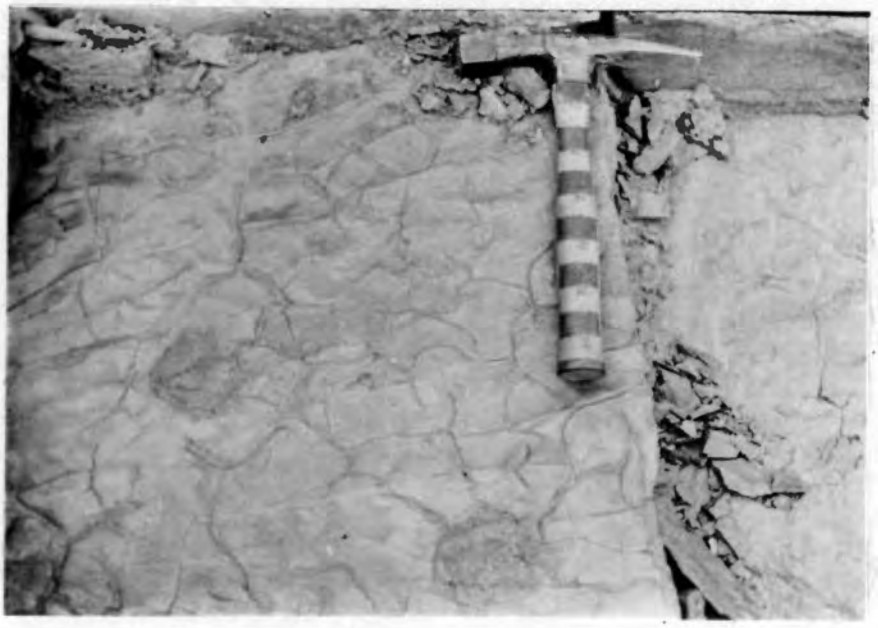

Figure 20. Small mud crack polygons, Porterfield Gap, unit 63, each unit on hammer is 2 cm. long.

red siltstone and very fine-grained sandstone. Crack filling in the dolomites is grayish to white, very fine-grained sandstone, while in greenish gray sandstone, the filling is silty to very fine grained greenish gray sandstone.

Mud cracks formed in the Rome tidal flats as a result of subaerial exposure and loss of water from sediments due to desiccation. The alternate wetting and drying on tidal flats as a result of flood and ebb currents produced cracks and polygons which were later filled with silt and very fine sand transported by tidal currents. The abundance of mud cracks in red beds which represent supratidal and mud flat environments indicates that these two zones were subaerially exposed to desiccation for longer periods of time compared to other parts of the tidal flat.

The possibility that mud cracks in the Rome Formation might be subaqueous shrinkage cracks was considered. According to Donovan and Foster (1972), shrinkage cracks in their simplest form are elongate and tapered in plane view; they can also branch from a central point and assume a sinuous appearance. Subaqueous mud cracks typically occur in gray-black siltstone, while subaerial cracks are usually found in greenish or red sediments and are rare in gray-black silts. Subaerial cracks show a polygonal or rectangular plan, are larger in scale than linear cracks and their depth of penetration in vertical section is usually much greater. Mud cracks in the Rome Formation are interpreted to be of subaerial origin.

III. HALITE CRYSTAL CASTS

Halite crystal casts are fillings of cubic cavities left by the dissolution of salt crystals embedded in fine-grained sediment. Brooks

(1955) was the first to report the presence of halite crystal casts from the Rome at War Ridge, Grainger County, Tennessee. He indicated that the casts are 1 mm to 1 cm on a side and are preserved in relief on the underside of fine-grained, thin bedded sandstone and red mudrock. According to Brooks, halite crystals made the cubic impressions in the sediment and dissolved before fine sand was deposited over the sedimentary interfaces to fill the impressions. The filling of impressions by transported sediments is indicated by the presence of micro-cross laminae in the casts.

Brooks indicated that the cubic halite crystals form in saline, shallow pools on mud flats. Thompson (1968) found halite crystals in recent sediments of the supratidal zone in tidal flat sediments of the Colorado River delta but he did not report any halite crystal casts. Because the casts are filled with micro cross-laminated sediment and are located on the underside of beds, they are considered to be contemporaneous with the sediment in which they are found.

Halite crystal casts in the Rome of the study area range in size from 2 mm to 1 cm on a side (Figures 21 and 22). Halite casts in the study area are not confined to a single lithology or particular horizon in the Rome section. The casts occur on the underside of grayish red laminated to very thin bedded siltstone, dusky yellow siltstone and gray sandy dolomite. Impressions of the crystal casts are found on the upper bedding plane surfaces of beds. Halite crystal casts were collected from Pine Ridge I-75 (Appendix PR units 1/7, 35, 70/3), Oak Ridge unit, 27 and Porterfield Gap (Appendix PG units 8, 22, 24, 42, 47, 54, 63).

Figure 21. Halite crystal casts in grayish rea, very thin bedded siltstone, Oak Ridge, unit 27, cm. scale.

Figure 22. Halite crystal casts in grayish red, very fine grained, very thin bedded sandstone, Porterfield Gap, unit 8, cm. scale.

IV. RIPPLE MARKS

Ripple marks consist of numerous, essentially parallel, long, uniformly spaced ridges and troughs, trending in straight or gently curved lines at right angles to the current. Symmetrical and oscillation ripple marks are abundant in the Rome Formation; they are not restricted to any particular type of lithology. Ripple marks exhibit sharp and rounded crests with wave lengths of several centimeters and amplitude of one centimeter or less. In some units in the Rome Formation, they are associated with mud cracks in red beds indicating that ripples formed on a mud flat. Twenty-four measurements of azimuthal directions of ripple marks in the study area show a mean paleocurrent direction of 103°. The large variety of ripple marks in the Rome Formation have been described and illustrated by Harvey and Maher (1948) and Spigai (1963).

V. RAIN PRINTS

Rain prints are small circular pits formed in soft sediment, usually mud. Rain prints in the Rome Formation are hemispherical depressions about 1 mm deep and 2 mm in diameter (Figure 23). Rain prints and their casts were collected from a laminated, grayish red silt-stone bed in unit 63 at Porterfield Gap, the only section that exhibited these structures in the same unit with halite casts, mud cracks and ripple marks. These structures point to the persistence of subaerial conditions in the Rome. Harvey and Maher (1948) reported the presence of rain prints from Poor Valley Ridge, Grainger County, while Spigai (1963) reported their presence from Dug Ridge, Roane County, both in Tennessee.

Figure 23. Rain prints, Porterfield Gap, unit 63, cm. scale.

VI. TIDAL BALLS

Tidal balls are subrounded to well rounded pebbles made up of silty, very fine grained sandstone and coated with mud. The average diameter of these balls in the study area is 4 cm (Figure 24). One of these balls was sectioned and found to be made of laminated, silty, very fine-grained, grayish red sandstone. The balls commonly resulted from the breaking off of chunks of mud crack polygons on mud flats by storm waves, which rolled and rounded the chunks and coated them with mud. These balls are found only in red beds at Diggs Gap unit 11 and Pumphouse Road unit 3. Tidal balls of the Rome formed on a mud flat which is characterized by the abundance of mud cracks. Although mud flats are quiet environments, far from normal wave action, storm waves can reach these flats, pluck mud chunks and roll them around. Due to the relatively large size of the chunks, and incomplete lithification, they become rounded in a short time, probably during one storm.

VII. CROSS-BEDDING

Large scale cross-bedding in the Rome Formation is rare, but it was observed at the following localities in the study area: Pine Ridge, I-75 (units 5 and 126), Oak Ridge (units 56 and 58), Young Creek (units 12 and 22), Sharp Gap (unit 48/2) and Shooks Gap (unit 32). The thickness of cross-bed sets ranges from 5 cm at Sharp Gap to 56 cm at Pine Ridge. The dip of the cross-beds ranges from 20° to 30° with a mean direction of 165° for eight readings. Planar cross-bedding occurs in some very coarse grained sandstone and oolites. Trough cross-bedding occurs only in the Oak Ridge section in the oolite zone (unit 56). One common feature of most cross-bedded units is the presence of glauconitic

Figure 24. Tidal balls from Diggs Gap, unit 11, cm. scale

laminae which alternate with clean quartz sandstone (Appendix OR unit 58; SG unit 48/2) or oolitic laminae (Appendix PR unit 126). The cross-bedding in unit 5 at Pine Ridge I-75 does not have glauconitic laminae, instead it is made up completely of clean, well rounded, very coarse-grained sandstone.

The cross-bedded oolites no doubt indicate the effect of transportation by ocean currents in a shallow marine environment. From the mean direction of the oolite cross-beds (172°) probably longshore currents were responsible for their transportation and sedimentation. Cross-bedding in sandstones which alternate with glauconitic laminae might represent deposition in a very shallow littoral environment or small tidal gullies in which the glauconite was transported from the subtidal environment to the tidal flat by flood currents or storm waves. The very coarse-grained, cross-bedded, pure sandstone in unit 5 at Pine Ridge I-75 is found in red beds, suggesting deposition in a fluvial channel or a mud flat gully.

VIII. RIPPLE LAMINAE

Ripple laminae are the corresponding internal structures of ripple marks, which are surface forms. Both are formed in sand or silt by either currents or waves. Ripple laminated structures are formed of sand transported by ripple motion and therefore deposited largely from suspension. These structures appear as micro cross-lamination in cross-section (McKee, 1965).

Ripple laminae are abundant in the terrigenous clastic as well as carbonate units in the Rome Formation. The cross-bed sets dip in opposite directions indicating tidal influence wherein the dominant direction represents the flood current direction. The ebb currents on a tidal flat are typically stronger than the flood currents which deposits sediment in suspension, but ebb currents partially erode some of the sediment already deposited (Figure 25) (Reinck and Singh, 1973). Hand samples in the Rome do not typically show micro cross-lamination unless slabbed and polished. The significance of these structures is that well developed ripple laminae indicate the regular introduction of new silt and sand onto the tidal flat, while irregular horizontal laminae indicate that sediment is constantly being redistributed by flood and ebb tides without introduction of new sand (McKee, 1965).

IX. CURRENT LAMINATIONS

Current laminations are tabular sets of laminae within which the laminae are horizontal and consist of alternating layers of differing texture or color. Each lamina is less than 1 cm in thickness, but thickness of individual lamina may vary within a set (Figure 26). Current laminations (Visher, 1965) are referred to by Harms and Fahnestock (1965) as "horizontal stratification," while Coleman and Gagliano (1965) refer to them as "parallel laminations." These laminations are formed under subaqueous conditions and result from either a segregation of particles by differential settling initiated by changes in current velocity or from changes in water chemistry. The former produces textured variations and the latter color vaiations (Coleman and Gagliano, 1965).

Current laminations occur within the area of investigation in very fine-grained sandstones, siltstones and carbonates. They are found in more than 40 percent of the beds in the Rome Formation. The laminae are easily recognized because of their alternate dark and light colors. In

Figure 25. Photomicrograph of ripple laminae in the middle with disturbed current lamination below and above in grayish red very fine grained sandstone, Pine Ridge, unit 51, transmitted light, 4X.

Figure 26. Photomicrograph of current laminations in silty very fine sparry dolomite, Porterfield Gap, unit 57, transmitted light, 4X.

some red beds the dark laminae are due to the concentration of iron oxide, while the light colored laminae are due to the presence of cleaner sand and silt. Laminae are produced also as a result of alternate deposition of sandstone and green glauconitic laminae (Figure 27). In carbonates and especially dolomites the concentration of very fine-grained sandstone, siltstone, and glauconite in thin sheets produces these laminae. Some of the silty laminae in dolomites show normal graded bedding, indicating differential settling probably in a standing body of water. Current laminations in the Rome lithology are usually underlain or overlain by ripple laminations or by scour and fill structures (Figure 28). These laminae are usually destroyed by bioturbation and reworking by tidal currents.

X. SCOUR AND FILL

Scour and fill structures formed in shallow depressions which were scoured in loose consolidated bottom sediment under certain current-velocity conditions and variations in turbulence. Decreased current velocities result in various types of fill within the scoured depression (Shrock, 1948).

Scour and fill structures appear in sandstones, siltstones, and carbonates in the Rome Formation. They range in width from a few millimeters to several centimeters, while depth of scour is usually of the same order (Figure 29). Scour is found usually in current laminated beds, while the fill is made up of cross-laminations of the same lithology as the underlying laminae (Figures 30 and 31). Scour and fill structures were observed in some intraclastic carbonates of the Rome Formation (Figure 32). Reineck (1972) referred to scour and fill structures on

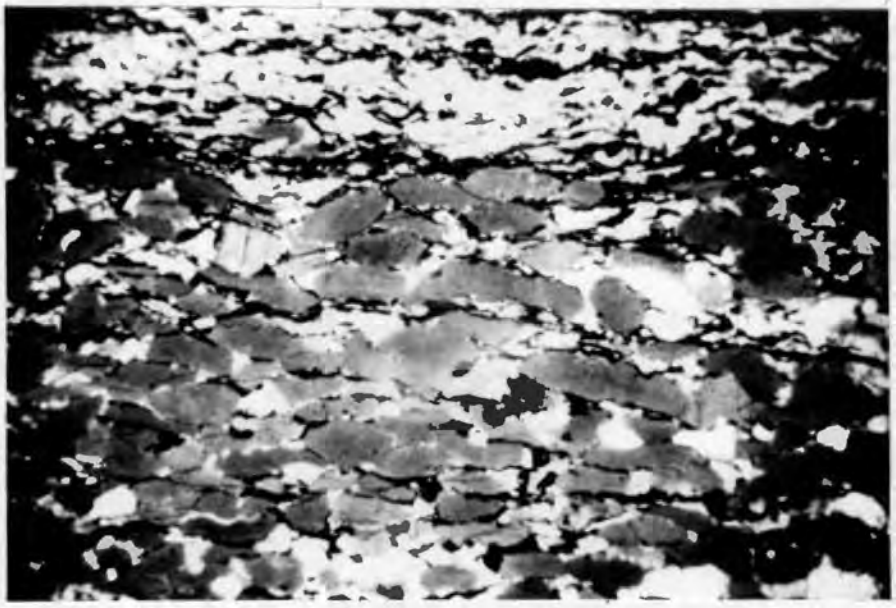

Figure 27. Photomicrograph of alternate glauconite (gray) and sandstone laminae (white) with intervening iron oxide laminae (black), Pine Ridge I-75, unit 104, transmitted light, 25X.

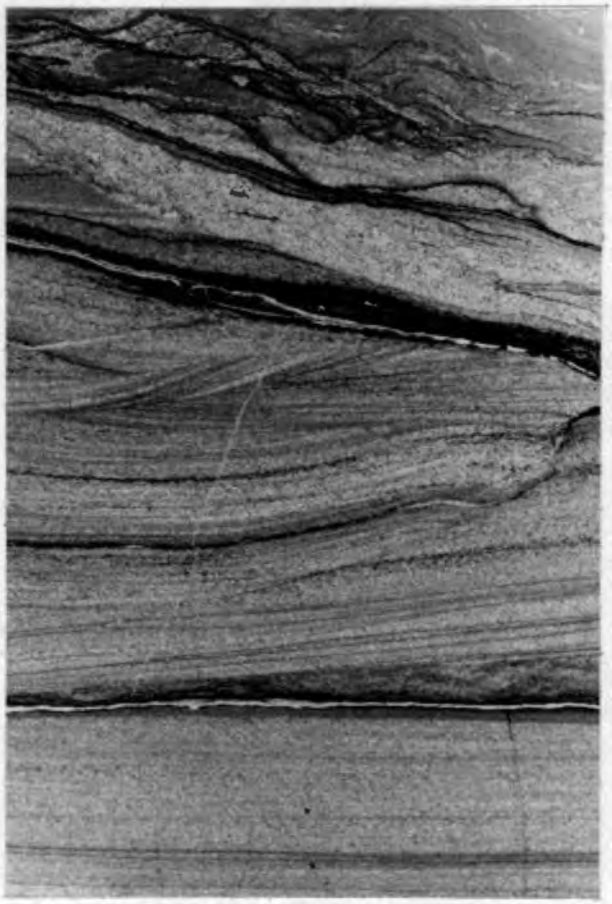

Figure 28. Photomicrograph of current lamination in silty dolomite pelsparite with micro cross laminae and scour and fill structures at the top, Sharp Gap, unit 7, transmitted light, 4X.

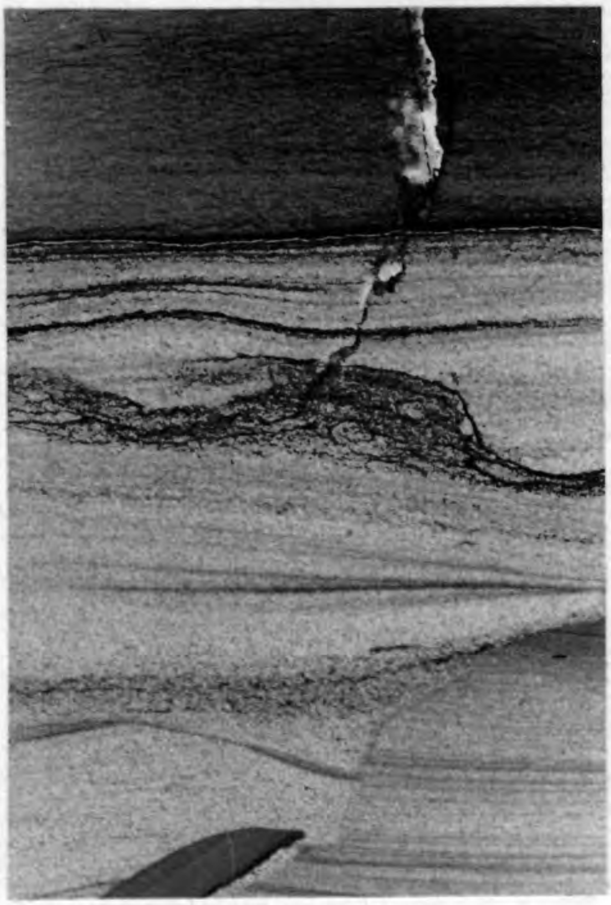

Figure 29. Photomicrograph of scour and fill structure in current laminated, silty dolomitic pelsparite. A large scour at the bottom with an intraclast and two small ones in the middle, Sharp Gap, unit 7, transmitted light, 4X.

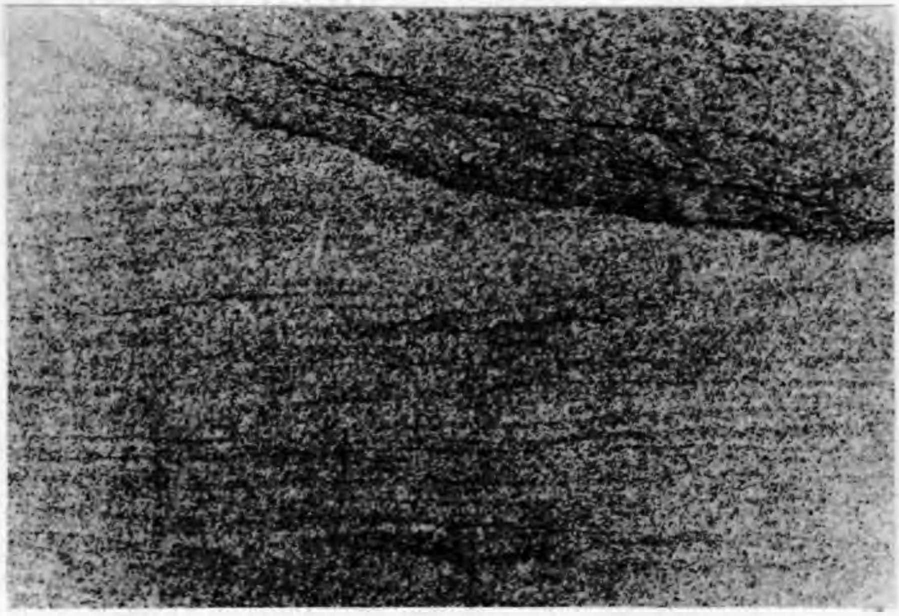

Figure 30. Photomicrograph of scour and fill structure in current laminated grayish red very fine grained sandstone, Oak Ridge, unit 38, transmitted light, 4X.

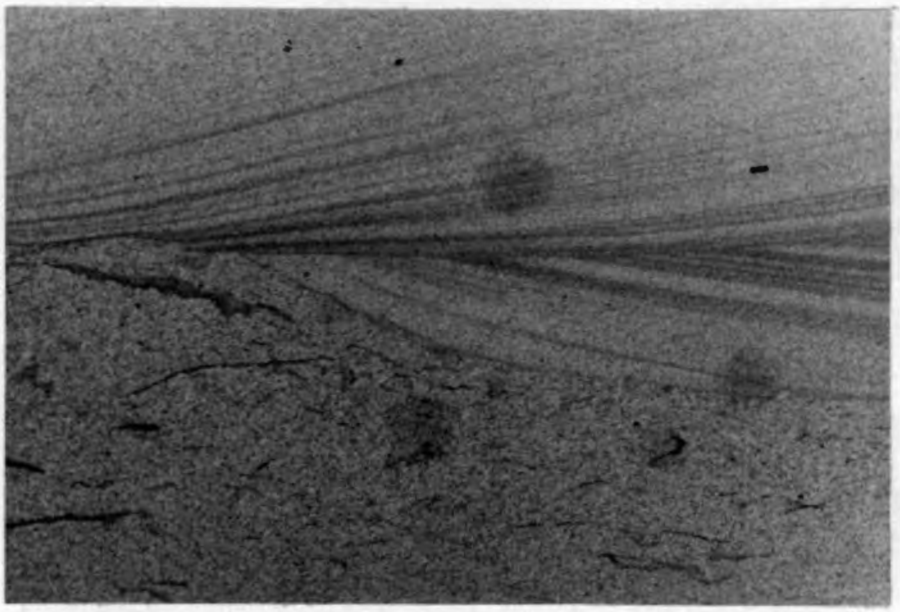

Figure 31. Photomicrograph of scour and fill structure in silty dolomitic pelsparite with micro cross laminae, Sharp Gap, unit 7, transmitted light, 4X.

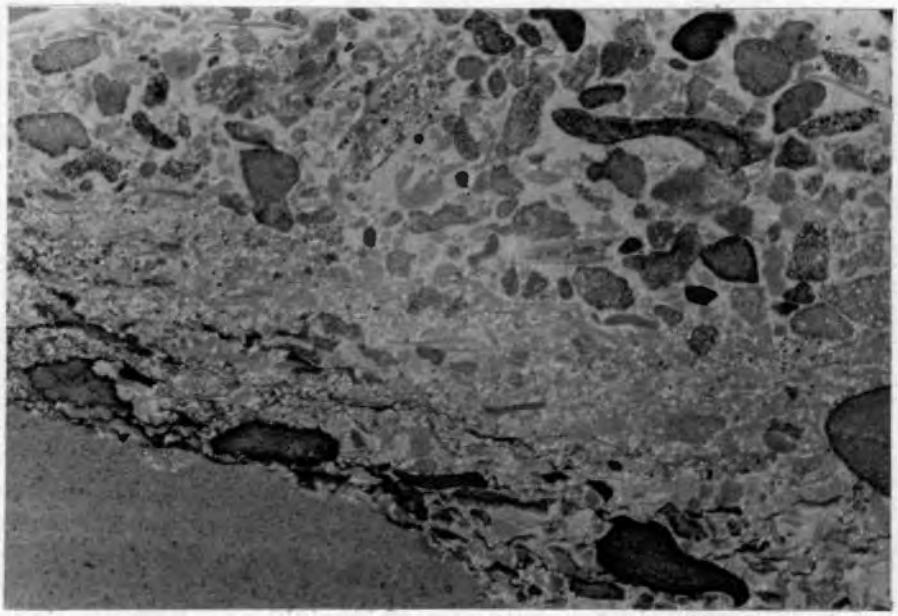

Figure 32. Photomicrograph of intraclastic limestone with a scour surface at the bottom, Young Creek, unit 10, transmitted light, 4X.

tidal flats as small scale erosional discordances. Reineck indicated that flood currents tend to deposit sediments on the tidal flats, while ebb currents and waves, which are stronger, tend to erode partially the top of the already deposited sediment.

XI. FLUTE AND GROOVE CASTS

A flute cast is a raised subconical spoon-shaped structure, the up current end of which is rounded or bulbous and the other end is flared and merges with the bedding surface. It is formed by filling of an erosional scour, while groove casts, are casts of straight linear depresssions or striations.

The above structures as described and illustrated by Pettijohn and Potter (1964, Plate 61) have been found in some debris samples in the Rome Formation at Pine Ridge I-75 and Porterfield Gap. In both cases the structures were found in silty very fine-grained grayish red sandstone which is a dominant lithology in the mud flat environment in the Rome. The flute casts are between 1 to 3 cm wide, less than ½ cm high and up to 6 cm long, while groove casts are no more than 1 to 2 mm wide, up to 1 mm high and very long. Both flute and groove casts were found in the same samples and are parallel to sub-parallel to each other. Although these sole marks indicate moderate to strong currents and are characteristic of turbidity-current and deep-water deposits, they have been reported from shallow water environments. Flute casts have been observed in shelf deposits, stream-cut channels and flood-plain deposits (Heckel, 1972); while groove casts were described in shallow water and on tidal flats by Reineck (1969).

XII. LOAD CASTS

Load casts described by Pettijohn and Potter (1964) as bulbous irregularities on the underside of a bed, result from the down sinking of the overlying sand into mud. Load casts are rare in the Rome in the area of investigation and have been observed only once at Porterfield Gap in a thin bedded sandstone.

XIII. VUGS

Vugs are irregular cavities, often with a mineral lining. Vugs were observed in unit 50 at Pine Ridge I-75 in a red silty sandstone bed. These vugs have no mineral lining and are 2 to 3 mm wide. These cavities probably result from the dissolving of the mineral material that originally occupied the cavity. The author believes that those cavities are left by the solution of evaporites from mud flat sediments in the Rome. According to Lucia (1972) evaporites are very suceptible to removal by shallow ground water. Therefore they are rarely well preserved in outcrops.

XIV. BIRDSEYES

According to Shinn (1968) birdseye structures are tiny blebs of calcite found in carbonate rocks ranging in age from Precambrian to Recent. The shape varies from planar, isolated voids 1 to 3 mm high by several millimeters in width to isolated bubble-like voids 1 to 3 mm in diameter both of which may be filled with calcite or anhydrite. Laboratory experiments and observations in limestone quarry tailings by Shinn, suggest that bubble-like vugs were made by gas bubbles and that planar vugs were made by shrinkage resulting from desiccation of exposed sediments. In ancient sediments birdseyes are associated with mud cracks and algal structures and are thus regarded as additional evidence for supratidal or high intertidal deposition.

Birdseye structures were seen in thin section in dolomite and limestone beds from Pine Ridge I-75 units 86 and 118 respectively. The structures are associated with crinkly algal laminae (Figure 33). Only the bubble-like void type was seen in the Rome. These structures are not abundant in the thin sections examined. Thus the presence of birdseyes in some beds in the Rome Formation confirms the presence of the supratidal zone.

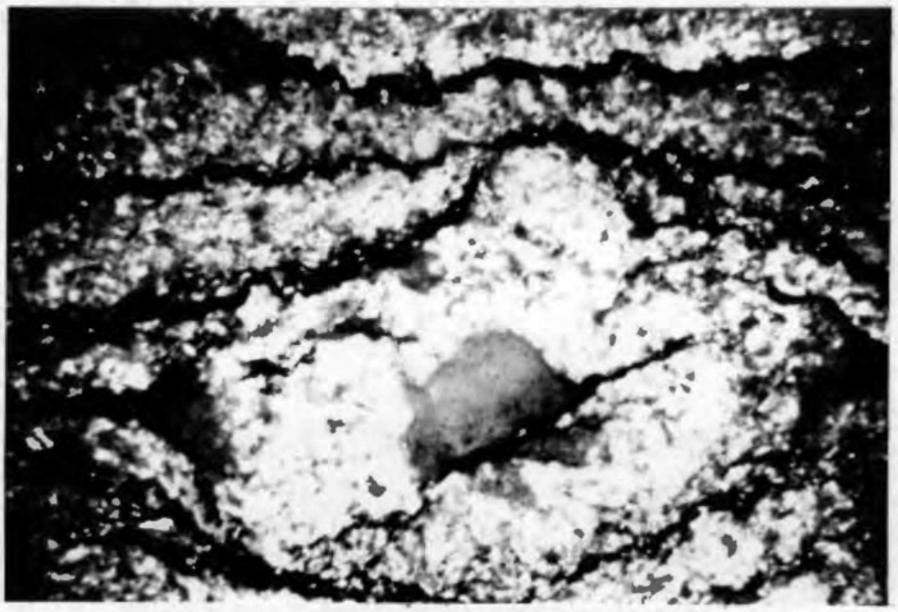

Figure 33. Photomicrograph of birdseye structure surrounded by crinkly wavy algal laminae, Pine Ridge I-75, unit 86, transmitted light, 25X.

CHAPTER V

BIOGENIC SEDIMENTARY STRUCTURES IN THE ROME FORMATION

I. INTRODUCTION

Body fossils are rare in the Rome Formation. The fossils which were reported by Woodward (1929), Resser (1938), Butts (1940), Rodgers and Kent (1948) (Table 5), were collected from widely scattered localities. Owing to the heterogeneous composition of the formation and to its structural complexities, the exact position of the fossils in the stratigraphic section in most localities is uncertain (Woodward, 1929; Butts, 1940). On the other hand biogenic sedimentary structures are very abundant in the Rome, and in some belts they can be used to correlate the Rome lithology along strike.

Seilacher (1964) defined trace fossils as sedimentary structures resulting from biological activity. According to him the advantages of trace fossils is that they have narrow facies range, that is the actions of organisms are usually direct responses to environmental conditions. He indicated that trace fossils are restricted to certain facies irrespective of which animals produced them.

According to Seilacher (1964) ichnofossils may occur in any type of sediment, but they are most abundant and best preserved in clastic series, particularly where sandy and shaly beds alternate as in the Rome Formation where most of the ichnofossils occur as positive hyporelief casts on sandstone surfaces underlain by shale. Trace fossils found in the Rome in order of decreasing abundance are: Planolites, Skilithos,

Table 5. List of Rome Faunas collected from four areas. Compiled with modifications from Woodward (1929), Resser (1938), Butts (1940), Rodgers and Kent (1948).

Fauna	Location: Georgia	Alabama	Tennessee	Virginia
Trilobita				
Olenellus thompsoni Hall	x	x	x	x
O. rudis Resser	x	x	x	x
O. alabamensis Resser	x	x		
O. buttsi Resser	x	x		
O. halli Walcott	x	x		
O. romensis Resser and Howell				x
Ptychoparella buttsi Resser			x	x
P. sp.	x	x		x
Solenopleurella virginica Resser	x		x	x
Antagmus tennessensis Resser			x	
Linnarssonella tennessensis Walcott			x	
Litocodia typicalis Resser	x	x		
Periomma alabamensis Resser	x	x		
Dolichometopus productus		x	x	
Zacanthoides orientalis		x		
Paedumias transitans		x		
Wanneria halli		x		
Amecephalina poulsni Resser				x
Periommella sp.				x
Bathyuriscus bantius			x	
Acrocephalops exigua Resser (M)				x
A. teres Resser (M)				x
Alokistocare virginicum Resser (M)				x
A. typicalis Resser (M)			x	x
Anoria bantius Walcott (M)				x
Elrathiella buttsi Resser (M)				x
Glossopleurella buttsi Resser (M)				x
G. virginica Resser (M)				x
Solenopleurella minor Resser (M)				x
Alokistocare alabamense Resser (M)			x	
Brachiopoda				
Acrotreta buttsi Resser	x	x		x
A. kutorgai		x		
Obolus smithi Walcott	x	x		
O. pandemia Walcott	x	x		
Paterina major Walcott	x	x		
P. williardi Walcott	x	x		
Wimanella shelbyensis Walcott	x	x		
Micromitra major		x		
M. williardi		x		

Table 5. (Continued)

Fauna	Location			
	Georgia	Alabama	Tennessee	Virginia
Mollusca				
Salterella sp.	x	x		
Hyolithes wanneri Resser and Howell				x
H. sp.	x	x		
Porifera				
Archaeocyathus sp.	x	x	x	x

Rusophycus, Cruziana, Scoyenia, fecal pellets, Sinusites, Phycodes, Bergaueria, Diplicharites, Dimorphichnus and Monomorphichnus.

Planolites

Planolites are fillings of burrows about 1 cm wide that penetrate sediment in irregular course and direction (Figures 34 and 35). The sand and silt filled tubes were made by worms which passed the sediment through their alimentary canal (Hantzschel, 1962). Planolites in the Rome Formation range in width from 2 mm to 1 cm. They probably formed close to the sediment-water interface, since they are found mostly as positive hyporelief on lower bedding planes of sandstone beds. They are found also on upper bedding planes but are usually less than 5 mm in diameter. Planolites are not confined to a specific type of lithology, but occur in equal abundance in all Rome sections in the study area.

Fecal Pellets

Fecal pellets are small droppings 1 mm in diameter and 1 to 3 mm long found usually on shaly bedding planes (Figure 36) and associated with Planolites and trilobite traces. The pellets were probably produced by trilobites and organisms which produced Planolites.

Sinusites

Sinusites are trails in negative relief that could have been formed by the sinuous movement of almost any worm (Figure 37). The trails, approximately 2 mm wide and 2 mm deep, represent negative epirelief on the upper bedding planes of very fine sandstone and sandy dolomite.

Figure 34. Planolites, Young Creek, unit 8, cm. scale.

Figure 35. Straight Planolites, Nelson Branch, unit 19, cm. scale.

Figure 36. Fecal pellets, Porterfield Gap, cm. scale.

Figure 37. _Sinusites_, Porterfield Gap, unit 20, natural size.

They are found in Paleozoic sands and Recent beach sands and pond muds (Seilacher, 196 . Their presence in different lithologies in the Rome supports Crime 970) finding that they are facies - independent.

Phycodes

Phycodes are bundled cylindrical fillings of tunnels on lower surfaces of quartzitic beds. Some of them may show faint regular transverse fluting. They are considered by Seilacher to be feeding burrows (Hantzschel, 1962).

Phycodes exposed in the Rome Formation are up to 3 cm in diameter and up to 15 cm long. Some phycodes have faint transverse fluting, but most are smooth. Good examples of these trace fossils were observed in the Dug Ridge, Pumphouse Road, and Nelson Branch sections, all in the Bullrun Ridge belt. The Phycodes form a positive hyporelief on the lower bedding plane of greenish gray quartzitic sandstone which is underlain by greenish gray shale. At Dug Ridge, Phycodes are found on the same bedding plane with large Rusophycus (Figure 38), which belong to the Cruziana facies and so were formed in a sublittoral environment.

Bergaueria

Bergaueria are fillings of perfectly circular depressions about 3.0 cm in diameter and up to 2.0 cm in depth (Figure 39). The positive hyporelief is filled with siltstone or fine-to medium-grained sandstone. According to Crimes (1970) and Orlowski, et al. (1970) these traces were made by sea anemones. In the Rome they are found in clusters or small communities of up to six individuals. At Crippen Gap they are present

Figure 38. Phycodes and Rusophycus on the same bedding plane, Dug Ridge, unit 28.

Figure 39. Bergauria, Crippen Gap, unit 35, cm. scale.

in dusky yellow, shaly siltstone at the top of the section, while at Dug Ridge they are present in greenish gray, fine-to medium-grained sandstone in unit 8. Since sea anemones were probably filter feeders or passive predators, the presence of their traces indicates a solid substrate, and turbulent marine waters. Crimes (1970) included Bergaueria in the Cruziana facies because its presence indicates a subtidal environment.

Scoyenia

Scoyenia represent very short vertical tubes in red beds of non-marine origin (Seilacher, 1967). Although the Rome Formation is full of red beds, the four locations where such short vertical tubes were seen by the author, are Pine Ridge I-75, Nelson Branch, Crippen Gap and Sharp Gap section. They are found in grayish red, very fine-grained thin bedded sandstone. The burrows, up to 3 mm in diameter and 1 to 2 cm long are filled with red siltstone and mud. These burrows were probably made by small worms. In those sections (Plates 1, 2, 3, 4) Scoyenia are found above the Skolithos beds, indicating more continental conditions and shallowing upward in the Rome Formation. This vertical sequence reflects the horizontal spacial distribution of these facies in the Rome environment.

Skolithos Facies

Skolithos are vertical tubes or tube fillings, 0.2 to 1.0 cm in diameter, in sandstones, usually straight and never branched, commonly but not always closely spaced (Hantzschel, 1962). Skolithos are attributed to suspension feeding worm-like organisms during periods of negligible sedimentation (Selley, 1970). In the Rome Formation Skolithos are 3 to 5 mm in diameter and not more than 4 cm long (Figures 40 and 41). Rome sections at Pine Ridge I-75, Oak Ridge, Young Creek, Nelson Branch, Crippen Gap, Sharp Gap and Porterfield Gap have Skolithos tubes which are filled with grayish red silty to very fine sandstone. Empty Skolithos tubes were found at Crippen Gap only. The importance of the Skolithos zone is that it indicates beach environment, while its position above the oolite zone makes it useful in correlating Rome stratigraphy in the area of investigation. In the Pine Ridge sections and Sharp Gap, Skolithos occurring above the oolite zone are in greenish gray thin bedded quartzitic sandstone interbedded with thin coarse sandstone beds (Plates 1 and 4). Although Skolithos tubes are found in beds below the oolite zone, e.g., Young Creek section unit 6 (Plate 1), the most prominant Skolithos zone is the first one to occur above the oolite zone. In this zone Skolithos are abundant. They are also found in up to ten thin beds, like Pine Ridge I-75 unit 127. In the Crippen Gap section, the upper Skolithos zone is the most prominent. It occurs in quartzitic sandstone unit 31, while Skolithos in unit 5 are found only in one thin bed. At Nelson Branch, where there is no oolite zone, Skolithos are found in pale yellowish brown quartzitic sandstone unit 13 (Plate 3). Skolithos at Porterfield Gap are found below the oolite zone in unit 55 in dolomitic sandstone, but they do not form a prominent zone. The Skolithos zone at Sharp Gap is separated from the underlying dolomitic oolites and intraclasts by grayish red sandstone. This sequence indicates a change from very shallow subtidal to intertidal environments.

Crimes (1970) in his study of the Lower and Middle Cambrian successions in Wales, found that Skolithos occurs immediately above known

Figure 40. Empty Skolithos tubes, Crippen Gap, unit 31, cm. scale.

Figure 41. Skolithos tubes filled with grayish red siltstone, Crippen Gap, unit 31, cm. scale.

surfaces of disconformity or unconformity, while traces belonging to the Cruziana community occur more commonly a few meters above the basal Arenig Lower Ordovician unconformity in sediments indicating sublittoral environments.

Cruziana Facies

Diplichnites

Diplichnites are biserial walking tracks of arthropods with numerous steps, similar to Cruziana but the traces reflect the limbs of trilobites touching the surface of the sediment rather than digging in (Crimes, 1970). Most of the Diplichnites in the Rome Formation were found in grayish red very thin bedded sandstone in which most of the traces are faint (Figure 42). A few of these traces were collected from grayish and greenish gray very thin bedded sandstone at Nelson Branch and Pumphouse Road sections. According to Crimes (1970) the width of the trace depends on the size of the animal and how far its limbs are extended outside or contained within the limits of the body. He claimed that the width of the trace depends on the speed of movement of the animal. The faster it moves the narrower is the trace, because the limbs are tucked inwards. So the width of the trace is only an approximation of the width of the trilobite. Diplichnites as much as 4 cm wide were collected from the Rome exposures and their width coincides with most Rusophycus and Cruziana found in the formation.

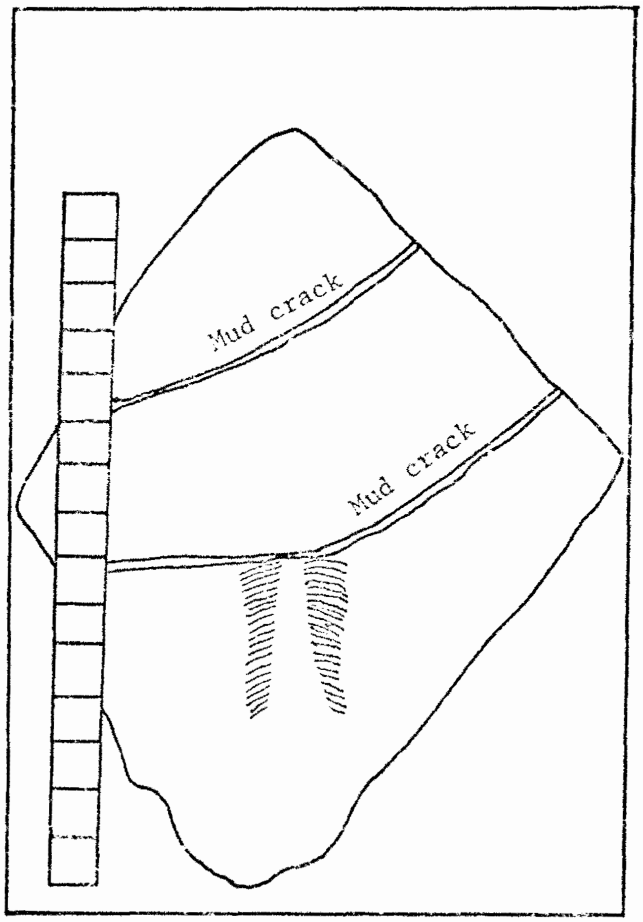

Figure 42. A line copy of Diplichnites from a photograph. Sample is from Shipe Road, Sharp Ridge about 16 km. NE of Knoxville. Each unit on scale is one cm long.

Dimorphichnus

Dimorphichnus are short, straight scratches irregularly arranged and considered to be sideways grazing traces of trilobites (Crimes, 1970). Samples of these traces were collected from grayish red, very thin bedded sandstone with shaly bedding planes (Figure 43). Their presence suggests that trilobites visited tidal flats during high tide or probably crawled across the flats back to sea when the tide ebbed.

Monomorphichnus

Monomorphichnus are forked elongate ridges arranged in echelon. They are considered to be swimming grazing traces made by trilobites (Crimes, 1970). A sample collected in thin bedded red sandstone at the Nelson Branch section had scratches which are about 2 mm deep, 3 cm at one end and 5 cm long on the other (Figure 44). Samples collected from Dug Ridge, Shipe Road and Young Creek sections come from grayish red thin bedded sandstone with shaly bedding planes. Ripple marks associated with *Monomorphichnus* indicate that these traces were made by trilobites on the tidal flats at high tide.

Rusophycus

Rusophycus is a bilobate coffee-bean shaped structure with transverse markings and a deep median groove (Figure 45), considered to be a typical resting track made by trilobites (Hantzschel, 1962). The Rome Formation in the study area, provided an abundance of *Rusophycus* (Figure 46), and in many cases associated with *Cruziana*. Most of the

Figure 43. Dimorphichnus from Shipe Road, Sharp Ridge, about 16 km. NE of Knoxville, cm. scale.

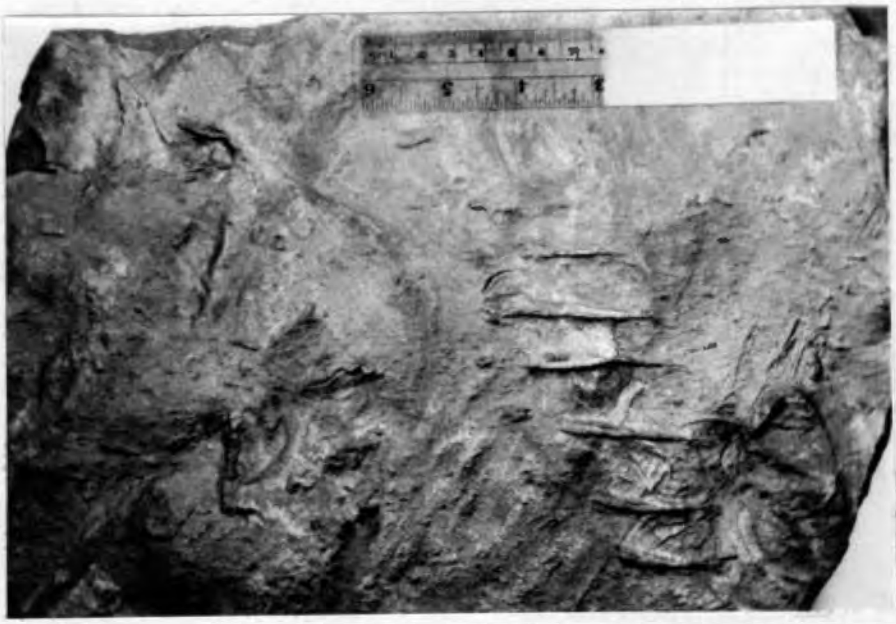

Figure 44. Monomorphichnus, Nelson Branch, unit 19, cm. scale.

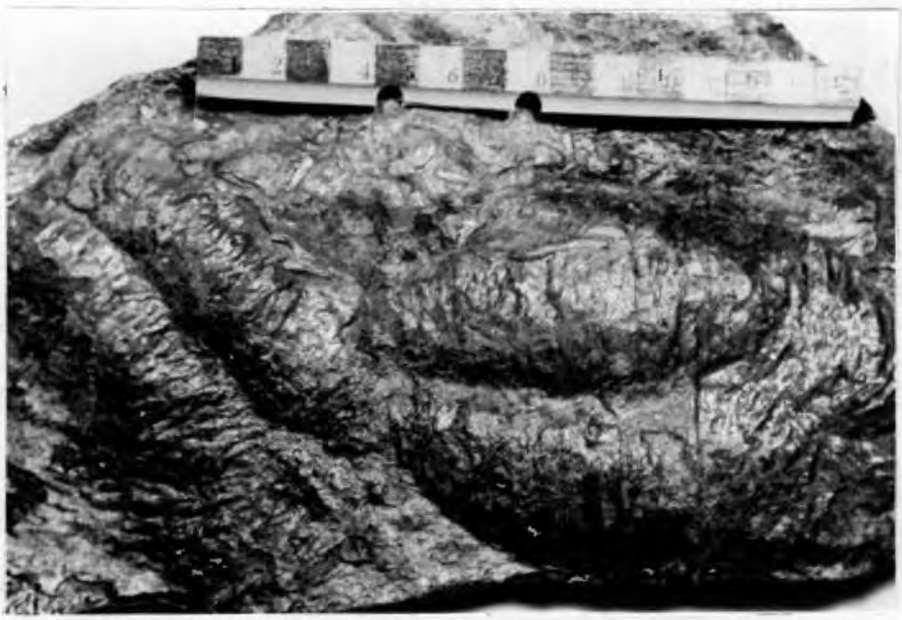

Figure 45. Rusophycus, Porterfield Gap, top of unit 59, cm. scale.

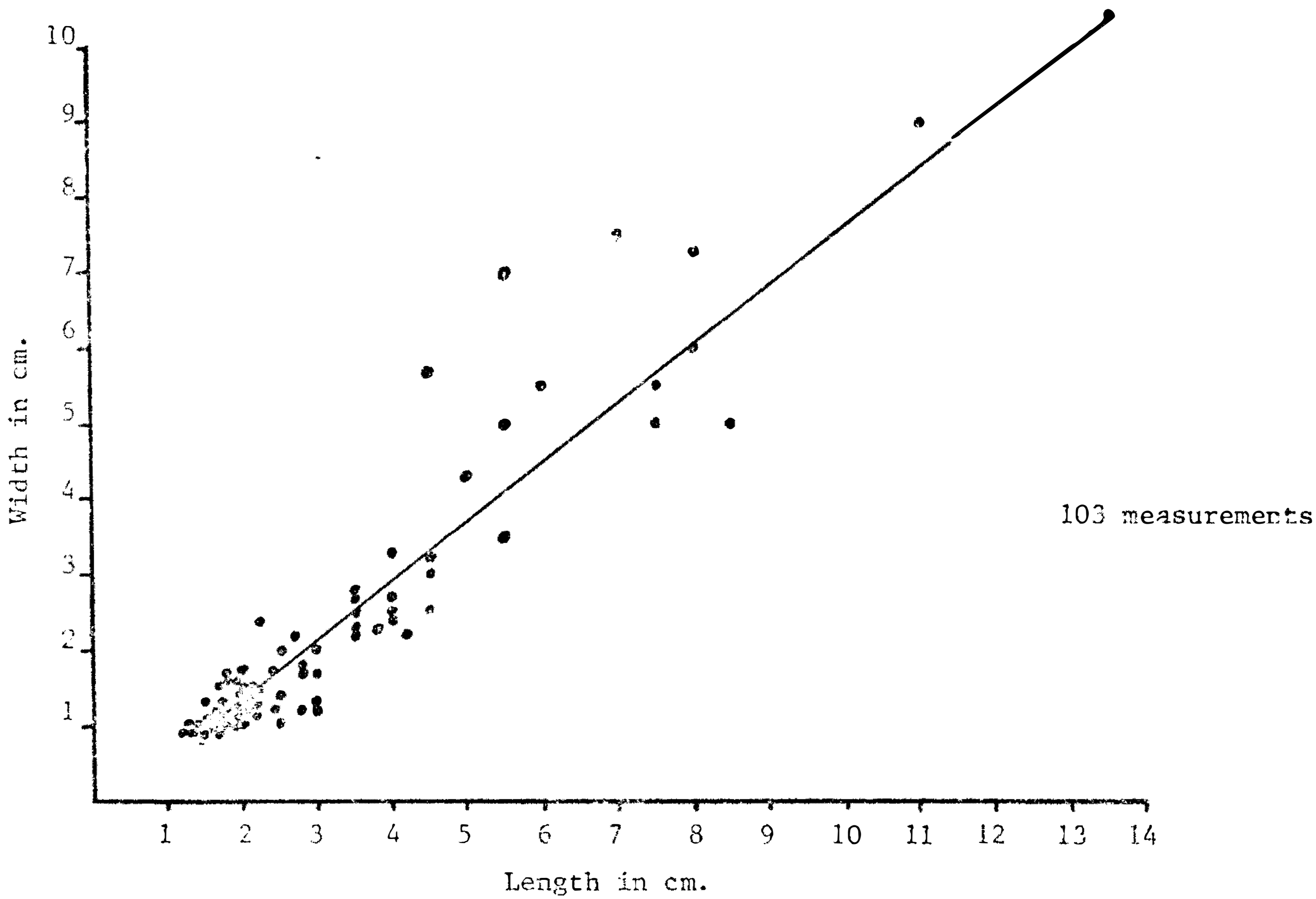

Figure 46. Graph of length against width for Rusophycus from all the Rome outcrops in the study area.

small size Rusophycus, 4 cm wide and less, were found in red beds associated with mud cracks and tidal balls which indicate intertidal to supratidal environments. Although Rusophycus are found in greenish gray sandstone and sandy dolomite, the probability of finding these traces in those beds is much less than grayish red very thin bedded sandstone alternating with red shale. The exceptionally large Rusophycus at Porterfield Gap were found in pale greenish siltstone below the oolite horizon (Plate 5). While some of the resting tracks are regular ones (Figure 45) the others represent a procline resting track which shows impression of the cephalic rim in which the trilobite maintained a head down position while digging (Figure 47). The presence of these tracks below the oolite horizon indicates a subtidal environment.

Cruziana

Cruziana are the casts of shallow pocket-like pits produced by trilobites furrowing through the sediment (Figure 48), the V-shaped markings being dug by inward and posteriorward motion of the endopodites (Seilacher, 1970; Crimes, 1970). Cruziana in the Rome Formation were found to be abundant in red sandstone. They occur on the same bedding plane with Rusophycus or in vertically adjacent beds. The largest Cruziana (8.5 cm) was found at Crippen Gap in greenish gray fine-to-medium-grained sandstone. A sample with a similar size in red sandstone was collected from debris. According to Seilacher (1970) the coarse transverse markings were made by the front endopodites representing a procline position while the trilobite was furrowing through the sediment. Judging from the size of the track, the trilobite must have been large and so the size of the endopodites would be proportional to the size of the body.

Figure 47. Procline resting tracks, Porterfield Gap, top of unit 59, cm. scale.

Figure 48. Cruziana, Dug Ridge, unit 25, cm. scale.

Rusophycus and *Cruziana* are found in grayish red sandstone, greenish gray sandstone and medium gray sandy dolomite. These trace fossils are most abundant in red beds and least abundant in dolomite. At Porterfield Gap section the large resting tracks in greenish gray siltstone below the oolite horizon represent a shallow subtidal environment, while the red beds above the oolites are full of sedimentary structures indicative of subaerial conditions; these structures include halite casts, rain prints and mud cracks. The whole sequence represents shallowing upwards and a gradual change from subtidal siltstone through oolites to red beds. The large trilobites were confined to subtidal marine waters and lived in small scattered communities. The trilobite traces in red beds are much smaller (less than 4 cm wide), and represent trilobites which frequented the mud flats and lived there temporarily.

The Bullrun Ridge sections at Diggs Gap and Nelson Branch provided the largest number of *Rusophycus* and *Cruziana*. In both sections the trilobite traces were found abundantly in grayish red, very thin bedded sandstone with shaly bedding planes. Mud cracks and tidal balls were found in these units and sometimes on the same bedding plane as the trace fossils (Figure 49). *Cruziana* in these beds criss-cross each other (Figure 50), indicating that trilobites were crowded in small pools on tidal flats. These trilobite traces occur in three or four beds, each 1 to 2 cm thick directly above each other, indicating that sedimentation was probably fast, possibly between two high tides. In other Rome sections *Rusophycus* and *Cruziana* were collected from greenish gray sandstone and grayish red sandstone indicating subtidal and intertidal environments respectively.

Figure 49. Mud cracks cutting across Cruziana, Nelson Branch, unit 10, cm. scale.

Figure 50. Crowded and criss crossing Cruziana, Diggs Gap, unit 11, cm. scale.

The Cruziana facies in the Rome Formation is therefore not restricted to the sublittoral zone. Selley (1970) found that Cruziana occurs in silt filled abandoned channels in the Lower Paleozoic of Jordan; he attributed the presence of trilobite traces in those sediments to the impinging of braided alluvial plains on marine shorelines where sea water infilled the distal ends of channel systems during a dry period, allowing marine organisms to inhabit fluvial channel systems temporarily. Selley concluded that Cruziana in the lowest facies is much less marine than the Skolithos facies.

According to Seilacher (1970) the absence of trilobite body fossils in some ichnofacies is that sands are too permeable to retain their shelly fossils during diagenesis; moreover, burrowing arthropods are usually less calcified, and thus less likely to be preserved. According to Seilacher (1964) the best preservation of Rusophycus and Cruziana is where sandstone and shale alternate, because trilobites preferred living on muddy clayey substrates which are ideal for preservation of body fossils. Sandstone provided the cast of the trace which was dug in clay mud by the trilobite. The author believes that many of these trilobite traces in the Rome were made by soft bodied trilobites. Although it is difficult to prove this point, the main functions of Cubichnia and Repichnia - that is Rusophycus and Cruziana - are hiding and grazing. Trilobites would hide temporarily during moulting and shedding of the exoskeleton, or permanently as a way of life if they were soft bodied. The many trilobite-like soft-bodied forms found in the Upper Precambrian Ediacara Formation of South Australia, and the Cambrian Burgess Shale of British Columbia (McAlester, 1968) support this idea. Crimes

(1970) indicates that during the early stages of development, trilobites moult frequently, during which time they buried themselves in mud for protection. He did not discuss the absence of trilobite body fossils from sediments associated with trace fossils.

Ichnofacies Model in the Rome

Seilacher (1964, 1967) has shown that trace fossils can be useful as environmental indicators. A clear relationship between sedimentary facies and the morphology of the trace fossils occurring in these facies is partly displayed in the Rome Formation. Such a relationship also demonstrates the wide ecological diversity attained by animals in the Lower Cambrian.

In the Rome Formation Scoyenia and Skolithos are restricted to supratidal and intertidal environments respectively. The Cruziana facies of Seilacher is restricted to the subtidal zone (Figure 51); but in the Rome Formation it overlaps the Scoyenia and Skolithos facies and so extends to the supratidal environment (Figures 52 and 53). Crimes (1970) noticed that few traces among the shallow-water forms are restricted to a single ichnofacies or community. He recognized three types of trace fossils:

1. "Facies - independent" occurring with similar frequency in all ichnofacies.
2. "Facies - influenced" occurring much more commonly in sediments of one ichnofacies.
3. "Facies - specific" restricted to one ichnofacies.

He found that Planolites and Sinusites are facies indepent, while

ICHNOFACIES MODEL OF SEILACHER

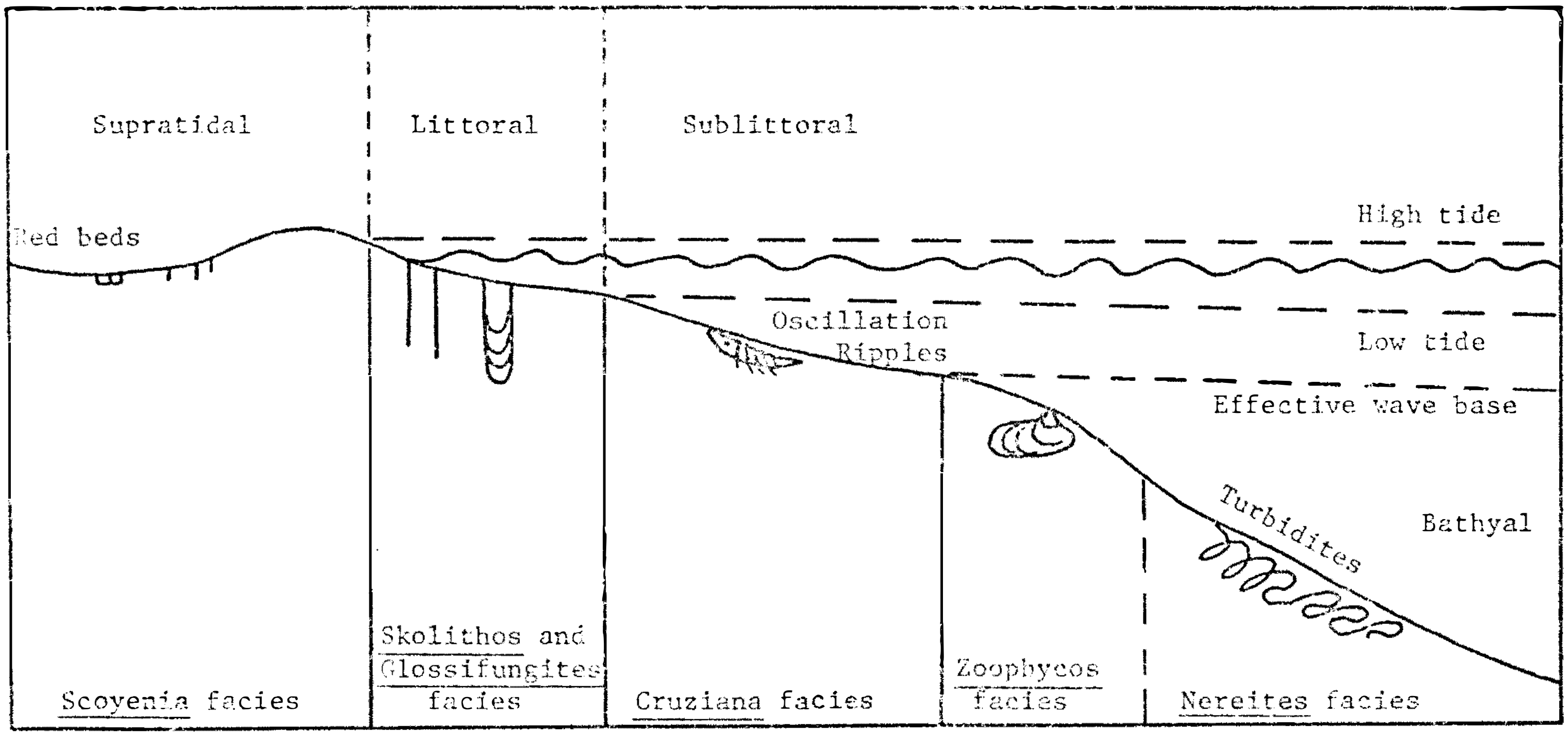

Figure 51. Bathymetric sequence of trace fossil communities in space (modified from Seilacher 1967).

ICHNOFACIES MODEL IN THE ROME

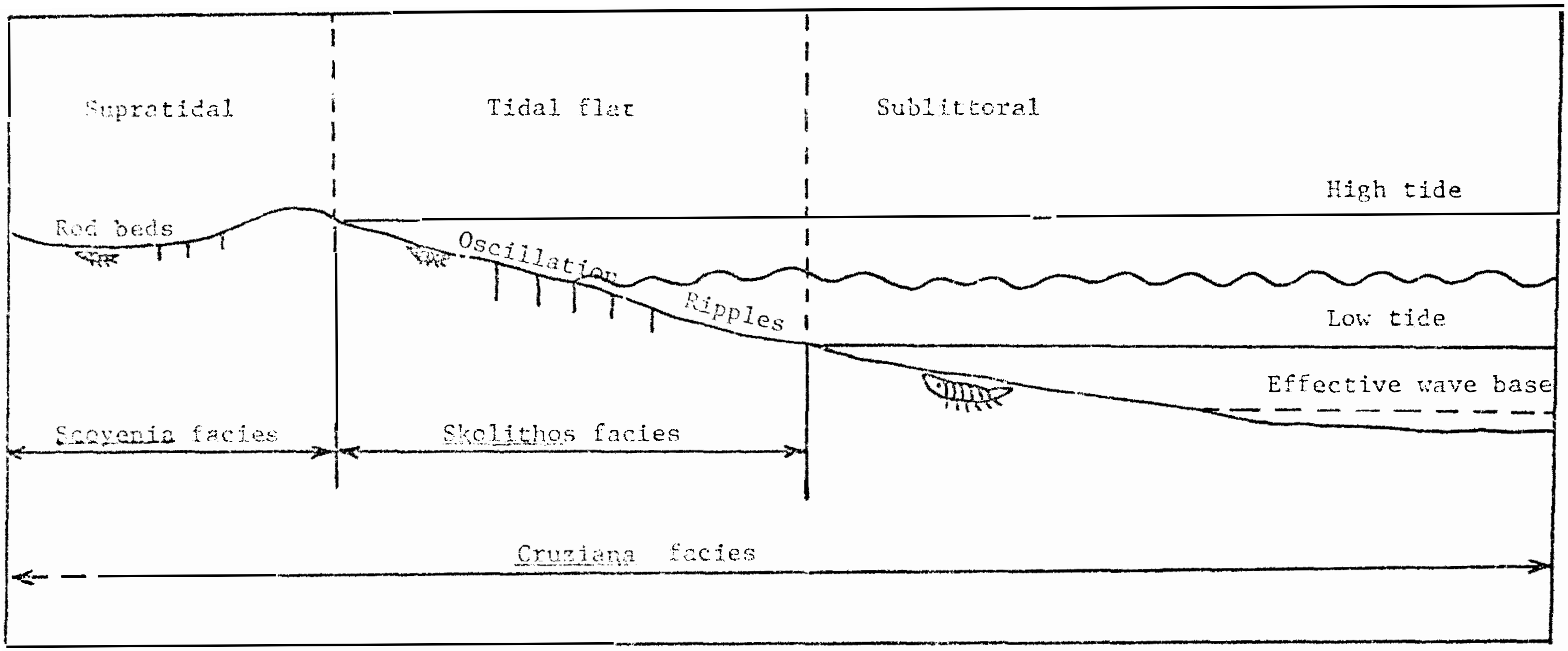

Figure 52. Bathymetric sequence of trace fossil communities in space in the Rome Formation. The width of the tidal flat zone is significant.

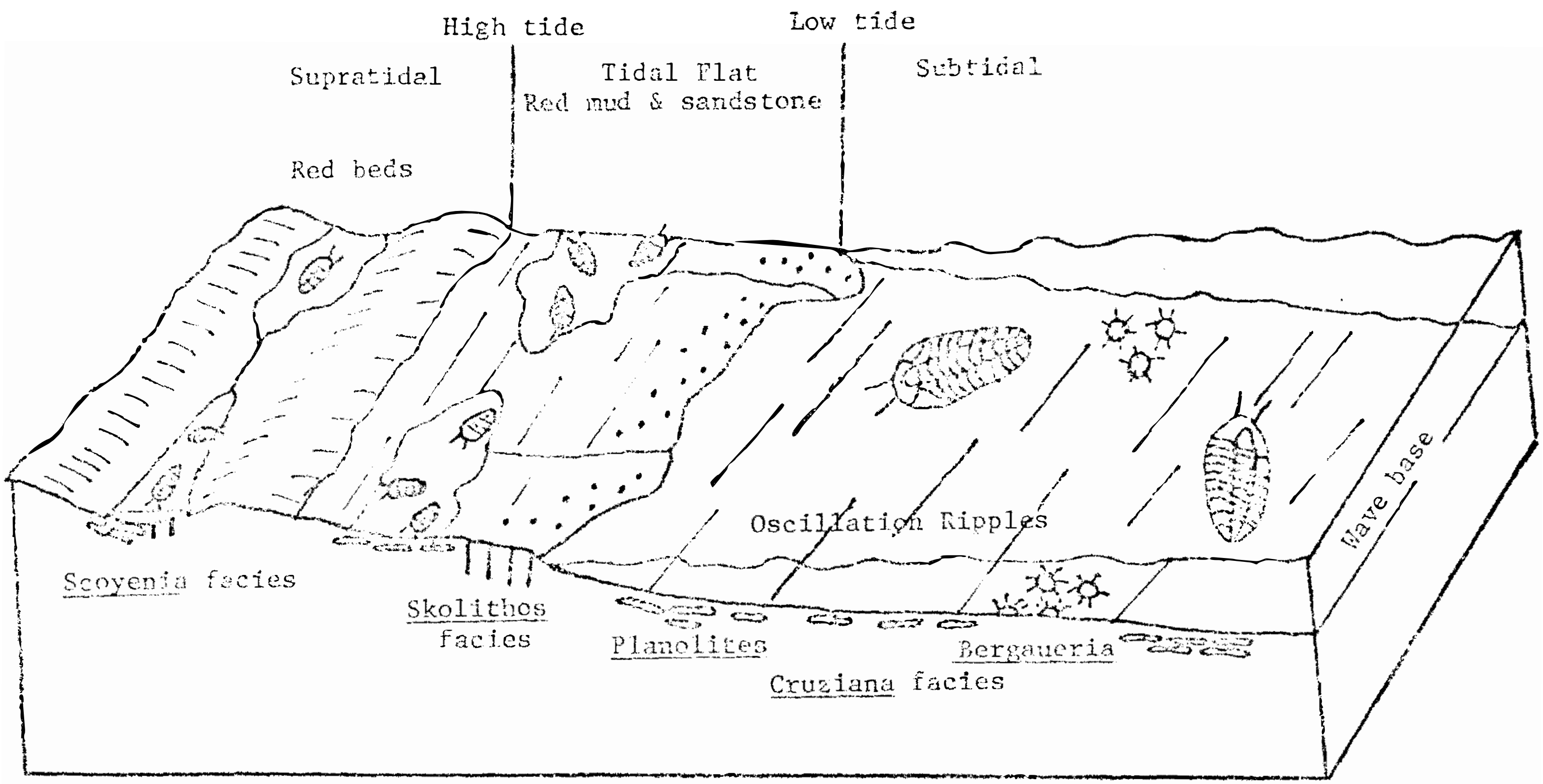

Figure 53. Block diagram showing the postulated environments of trace fossils during Rome time in East Tennessee.

Rusophycus and Diplichnites were facies influenced. He concluded that "facies influenced" are the most common, while "facies specific" are the least common. Planolites in the Rome Formation are found in most units, while Sinusites especially at Porterfield Gap section occur in siltstones and dolomite beds; so Planolites and Sinusites in the Rome are considered to be facies - independent. Trilobite traces in the Rome Formation taken as a whole would be considered facies - independent, but considering traces less than 4 cm wide, they would be regarded facies - influenced, since most of the trilobite traces less than 4 cm wide occur in red sandstones, while traces more than 4 cm wide are found in greenish gray sediments. The different sizes then, represent different facies and environments.

Conclusions

1. The presence of Cruziana carinata and Cruziana fasciculata - both of which are considered Lower Cambrian fossils (Seilacher, 1970) in the Nelson Branch and Porterfield Gap sections, supports the fact, that the Rome in the study area is Early Cambrian in age.
2. The Cruziana facies is not restricted to the sublittoral.
3. Trilobites were exposed to subaerial conditions either by crawling across the tidal flats back to water at low tide, or they waited for the next high tide to fill the tidal pools which they occupied.
4. The absence of trilobite body fossils from sediments associated with ichnofossils suggests that some trilobites were soft bodied, or that the body fossils were relatively fragile and destroyed during diagenesis.

From the measurements of Cruziana and Rusophycus (Figures 54 and 55) the following conclusions can be made:

1. None of the traces found were made by trilobites smaller than 0.9 cm in width.
2. The size range of Cruziana is the same as that of Rusophycus.
3. Rusophycus are more abundant than Cruziana in the study area.

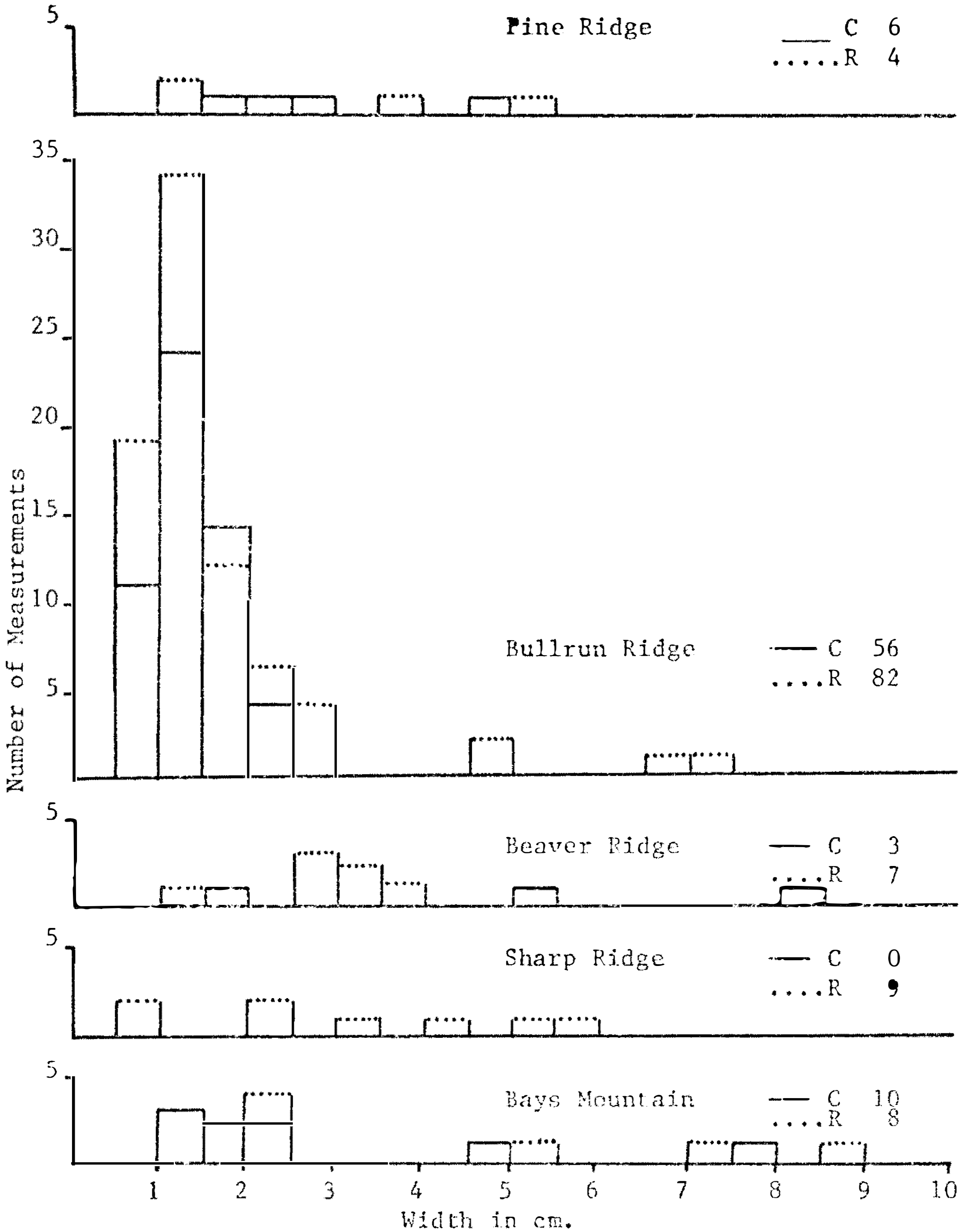

Figure 54. Size frequency histograms for Cruziana and Rusophycus from the different Rome belts in the study area.

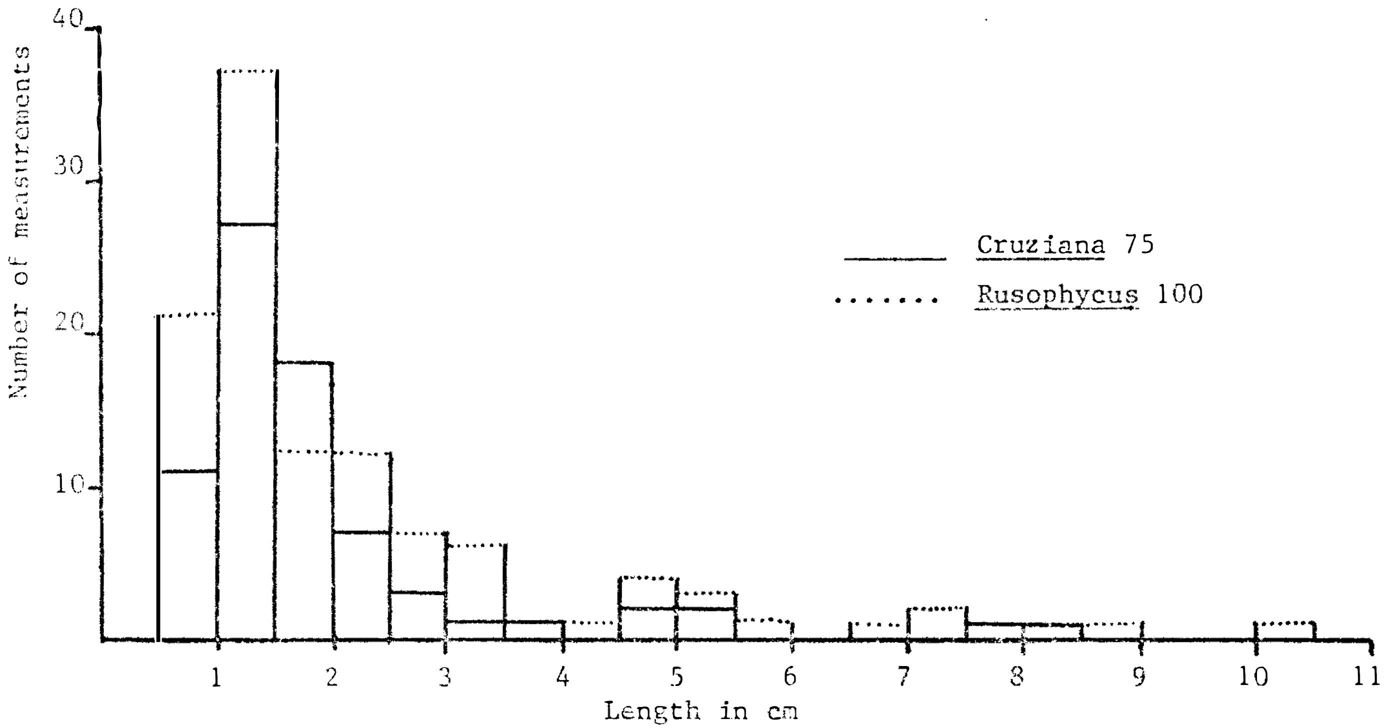

Figure 55. Size frequency histogram for Cruziana and Rusophycus from all outcrops of the Rome in the study area.

CHAPTER VI

ENVIRONMENTS OF DEPOSITION IN THE ROME

I. INTRODUCTION

Sedimentary structures in the Rome Formation, such as mud cracks, halite casts, flaser bedding, rain prints, tidal balls, birdseye structures in dolomite, algal laminations in carbonates, all point to a tidal flat type of environment. Landward of the tidal flat was the supratidal environment in which red beds and dolomite were deposited. Seaward, the tidal flat extended into the shallow subtidal zone with lagoons, oolite shoals and sandbars (Figure 56).

Recent studies of tidal flats by Reineck and Singh (1973), Heckel (1972), Reineck (1972), Raaf and Boersma (1971), Klein (1970), Thompson (1968), Reineck and Wunderlich (1968), Matter (1967) Reineck and Singh (1967) and Straaten and Kuenen (1957) indicated that the following features are diagnostic of tidal flat deposits.

1. Vectorial biomodality of cross-stratification.
2. Unidirectional cross-stratified sets.
3. Common occurrence of flaser and lenticular bedding.
4. Mud/sand interlamination.
5. Slight to intense bioturbation in sandy and muddy units.

Besides the above features, the Rome Formation exhibits many subaerial sedimentary features which leave no doubt that the Rome was deposited in a tidal flat, covered with mud cracks, spotted with calm tidal lakes and dissected by many tidal creeks. Such local subenvironments within a tidal flat account for the different types of lithologies in the Rome Formation.

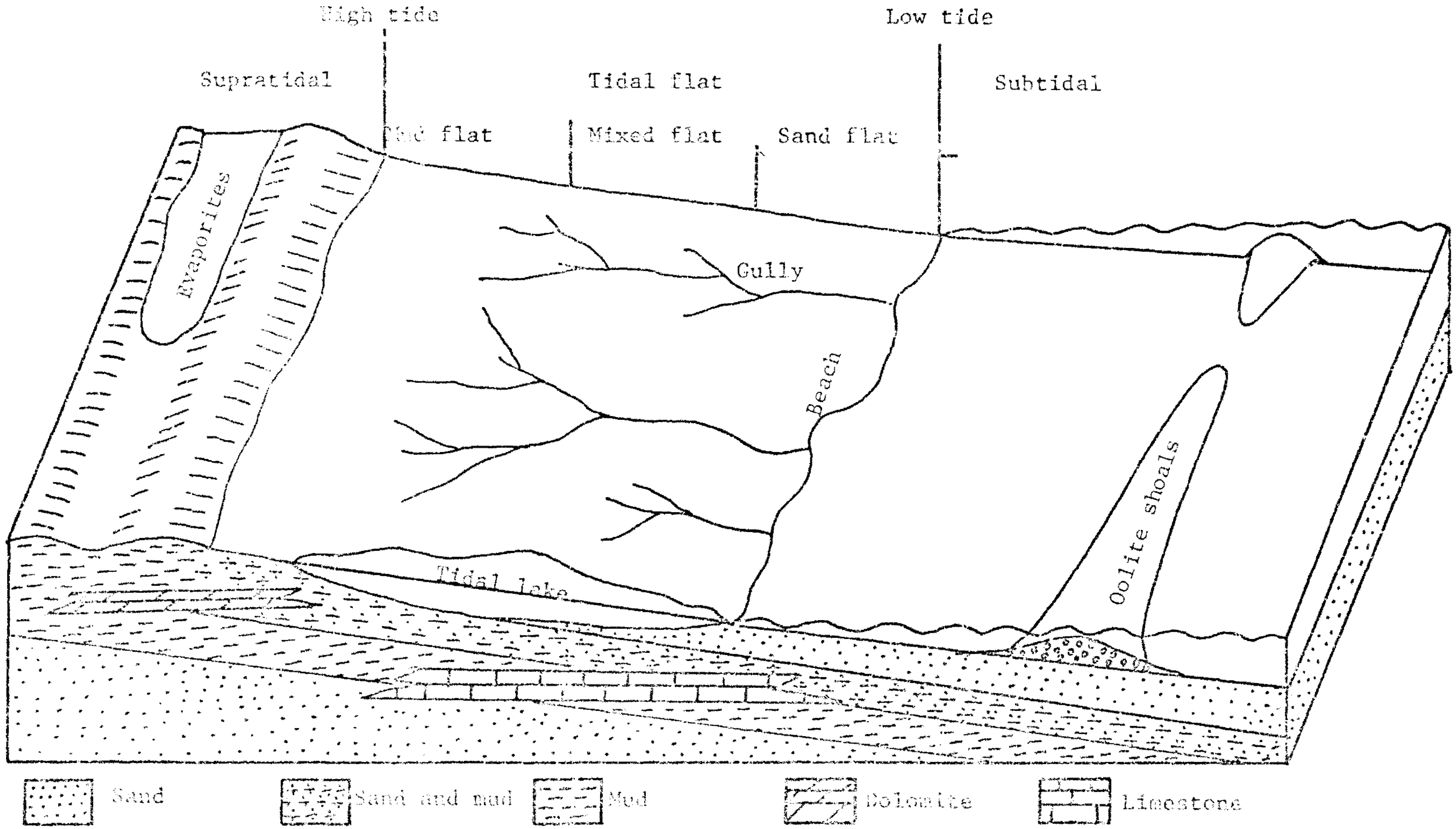

Figure 56. Postulated sedimentary environments in the Rome, and a transgressive sequence with lenses of carbonate rocks deposited in supratidal, intertidal and subtidal environments.

II. SUPRATIDAL ENVIRONMENT

The supratidal zone is located above mean high tide, where it is flooded only during very high spring tides (Figure 56). In modern warm and temperate climatic regions, the supratidal zone is vegetated by halophytic plants, e.g., the North Sea tidal flats (Reineck and Singh, 1973). In humid tropical climates mangroves are predominant, while in arid climates, such zones can be devoid of any vegetation, like the Colorado tidal flats (Thompson, 1968). Due to the high salinity in this zone, it is unfavorable for the survival of organisms. Reineck and Singh (1973), Singh (1968), and Thompson (1968) did not report any organisms living in modern supratidal zones. Biogenic structures appear to be rare in ancient supratidal sediments.

Supratidal sediments are distinguished by fine-grained clastics (Reineck, 1972; Thompson, 1968), red beds, (Walker, 1967; Van Houten, 1968, Dorsey, 1926); fine dolomites, birdseye structure, and flat or gently undulating, often mud cracked lamination, generally are more characteristic of the supratidal environment (Shinn, 1968; Illing, et al., 1965; Matter, 1967). Thompson (1968) recognized that laminated beds in the supratidal zone of the Colorado River Delta, are disrupted by mud crack formation and evaporite crystallization. He found that laminations in the subsurface contain two to three times more gypsum, and concluded that evaporites are still forming in the near surface muds of the supratidal flats by surface evaporation of tidal flood waters that occasionally reach the area.

The supratidal environment in the Rome Formation is characterized by the presence of red beds which are non-marine deposits. Dehydrated ferric oxide, which is responsible for the red pigment, is formed from weathering of iron-rich minerals in soils and alluvial deposits in warm, humid to arid climates (Walker, 1967; Van Houten, 1968; Dorsey, 1926). Evaporite crystals and mud cracks indicative of the supratidal zone (Thompson, 1968) are represented by halite casts and similar mud cracks in the Rome. These two sedimentary structures are abundant in the Porterfield Gap and Pine Ridge I-75 sections (Plates 1 and 5). Fine dolomites, birdseye structure and flat or gently undulating, often mud cracked laminations are recognized in some dolomite beds in the Rome Formation (Figure 33, page 77 and Figure 57).

Biogenic sedimentary structures in the supratidal environment of the Rome are rare. They are represented by short vertical burrows about 2 cm long and 2 to 3 mm wide in red beds referred to by Seilacher (1967) as <u>Scoyenia</u>. <u>Rusophycus</u> and <u>Cruziana</u> were also found in the supratidal environment. This interpretation is based upon the association of trilobite tracks with mud cracks, halite casts and rain prints in the same unit (Porterfield Gap unit 63, and Plate 5).

Three important criteria distinguish the supratidal sediments in the Rome, from sediments formed elsewhere on the tidal flat. First, the presence of <u>Scoyenia</u> in red beds; second, halite casts and mud cracks; and third, laminated dolomites with mud cracks and birdseye.

Recent supratidal sediments in the Colorado River Delta comprise a veneer 20 to 50 cm thick over much of the area. Even in subsurface cores these sediments are no more than 80 cm thick above the Pleistocene sediments (Thompson, 1968). This indicates that the supratidal sediments are vertically limited. The same is true of the Rome supratidal sediments which do not comprise more than 10 percent of the sections. The supratidal

Figure 57. Photomicrograph of mud crack polygon fragments and small intraclasts, made up of micrite, algal laminae at the bottom in dolomitic pelsparite, Sharp Gap, unit 8, transmitted light, 4X.

zones are not similar in position within the different sections across the strike, but rather occur randomly. In the Pine Ridge sections, the supratidal zones are limited to the lower half of the section and are confined to red beds or dolomites. These zones recur five times in the Pine Ridge I-75 section (Plate 1). At Porterfield Gap supratidal zones are found from the bottom of the section to the top with random repetition (Plate 5). The Crippen Gap section exhibits three zones of supratidal sediments, which are about equally spaced (Plate 3). In the Sharp Gap section only one zone could be identified above the oolite zone (Plate 4). The Nelson Branch section has one supratidal zone in red beds (Plate 2).

III. TIDAL FLAT ENVIRONMENT

The main part of the tidal flat is located between high and low tide (Figure 56, page 110). Tidal flats, develop along gently sloping sea coasts where the gradient is less than 0.5^{o}. Coasts with marked tidal rhythms, enough available sediments and minimum wave action are ideal for tidal flat development. Such conditions may be available in bays, estuaries, lagoons or behind sand bars and barrier islands.

Tidal flat sediments are deposited parallel to the shoreline over a distance of tens of kilometers, and are dissected by tidal channels and river estuaries like the North Sea tidal flats. Their sediments are mostly fine-grained sand, silt and clay. Coarse sediments are rare, but gravels, mud pebbles and shells are abundant in tidal channel deposits.

According to Reineck and Singh (1973) and Straaten and Kuenen (1957), tidal flats are divided into three zones (Figure 56):

1. Mud flat; near the high water line.
2. Sand flat; intertidal zone near low-water line.
3. Mixed flat; transition zone between the mud flat and the sand flat.

The reasons for this characteristic distribution of sediments on the tidal flats is that near the low-water line, wave activity is strongest and active for the longest time, thus sand is abundant due to the winnowing of mud, this gives rise to the sand flats. Mud deposition takes place in the mud flat near the high-water line mainly because wave and current energy is low. The two zones grade into each other giving rise to the mixed flat (Postma, 1961, Straaten and Kuenen, 1957).

Each of the three zones in a tidal flat is characterized by definite types of bedding, and varying degrees of bioturbation. On sand flats, small-scale cross-bedding of current ripple origin is common, while mixed flat is characterized by flaser, wavy and lenticular bedding. Mud flats consist mainly of thick mud layers with sandy intercalations. Most parts of the tidal flat surface sediments are bioturbated by benthonic organisms. Modern tidal flats are occupied by boring organisms such as arthropods, pelecypods and worms. Reineck and Singh (1973) found in the North Sea tidal flats, that bioturbation is generally strong in mud flats, weaker in mixed flats and weakest in sand flats. This is not always the case, because in small depressions on sand flats where mud is abundant, bioturbation is strong. Thompson (1968) reports strong bioturbation in part of the mud flats referred to in his study of the Colorado tidal flats as the "Crab Zone". The rest of the tidal flat is nearly devoid of bioturbation.

A comparison of ancient tidal flat sediments and modern ones, indicates that not all tidal flat characteristics are found in a single deposit; even modern tidal flat deposits show great variation from one tidal flat to another. The tidal flats of Germany have more mud than those of the Netherlands, while the tidal flats of Britain are rather sandy (Reineck and Singh, 1973). The Colorado tidal flats are sandy near the low-water line and muddy near the high water line (Thompson, 1968). Thus, differentiation between different zones in ancient tidal flat deposits, even between intertidal and subtidal deposits, is problematical (DeRaaf and Boersma, 1971).

Mud Flat

Mud flat is the intertidal zone near the high-water line, bounded by the supratidal zone landward and the mixed flat seaward (Figure 56, page110). It is the zone of mud accumulation, where clay, silt and very fine sand accumulate, due to the low wave and current energy near the high-water line.

Bedding in mud flats is characterised by thick mud layers with thin sandy intercalations. In mud flats of more arid climate, laminated beds are disturbed by mud cracks; the lower parts of the mud flat remain exposed to subaerial conditions 4 to 5 days, while the upper parts remain unflooded 8 to 10 days during neap tide periods (Thomspon, 1968).

Bioturbation in the mud flat is more intense than in the other parts of the tidal flat. Boring organisms such as molluscs and worms are abundant in mud flats of termperate zones like the North Sea tidal flats. In arid climates one or two species are dominant. In the Colorado tidal flats, the fiddler crabs hybernate during low tide when the mud flat is dry, but during high tide the wet mud flat becomes alive with and completely bioturbated by the crabs (Thompson, 1968).

The mud flat deposits in the Rome Formation are represented by red beds, abundant mud cracks (bottom of PR and PG, Plates 1 and 5), biogenic structures, bioturbation, and laminated shale, siltstone and very fine grained laminated to thin bedded sandstone.

Because sediments on mud flats are exposed subaerially for a longer time, compared to sand flats they are more oxidized. Another factor is that transported red sediments which are deposited in a well drained non-marine basin, retain their red color (Dunbar and Rodgers, 1957). This is illustrated by the abundance of mud cracks in red beds. Thus most of the red beds in the Rome Formation represent the mud flat zone.

Red beds make up 20 to 50 percent of the exposed Rome sections. In most sections red beds are more abundant at the bottom (PR, OR, YC, DG, NB, PH, BV, SG, AND PG, Plates 1-5). They form thick continuous zones at the bottom, but become discontinuous upwards. This trend represents a general transgressive sequence in the Rome, but red beds themselves represent a regressive sequence.

More than 80 percent of the Rusophycus, Cruziana and Planolites in the Rome are found in red beds (Appendix DG unit 11, NB unit 10, BV unit 26). The abundance of organisms accounts for the intense bioturbation in red beds (Figure 58). The reason for this bioturbation is that low current velocities on the mud flat result in stable substrates containing considerable proportions of mud and organic matter. The result is a bottom fauna dominated by deposit feeders. The organism which

Figure 58. Completely bioturbated red bed from the PR section with Planolites and trilobite tracks. Sample not in situ, scale 15 cm. long.

produced the trace fossil Planolites apparently caused most of the bioturbation in the Rome sediments, because they are more abundant than other trace fossils. The organisms which left their traces on the mud flats of the Rome are the trilobites and the worms.

Mixed Flat

The mixed flat is the gradational zone between the mud flat and the sand flat (Figure 56, page 110). It is characterized by flaser bedding, wavy bedding, lenticular bedding and alternate laminated sand and mud. This alternation of grain sizes results from conditions of varying current competency related to tidal current and slack water phases. Sandy layers are deposited by flood and ebb currents while mud is deposited during slack water periods (Straaten and Kuenen, 1958; Thompson, 1968).

Reineck and Wunderlich (1968) defined flaser bedding, as cross-bedding with numerous intercalated mud flaser (Appendix DG units 27 and 29). Wavy bedding develops when mud covers ripple crests and ripple troughs so that the surface of the mud follows the curvature of the under-lying sandy ripples (Appendix DG unit 16). In lenticular bedding, the ripples or lenses of sand are discontinuous vertically and horizontally (Appendix DG unit 16). These types of bedding develop in subtidal and intertidal zones, but there is no doubt that similar types of bedding in the Rome developed on the tidal flat, because they are associated with mud cracks and red beds (Appendix BV units 11 and 12).

Bioturbation is generally less intense in mixed flats because of the rapid alternation of laminated sand and mud. This type of environment does not provide the thick muddy substrate for benthonic organisms to burrow in. Tidal currents in this zone tend to deposit more sand than mud, and rework the sediment so frequently that biogenic structures, through they may form here, are usually destroyed. Partial erosion of already deposited sediments does not favor burrowing organisms, but as mentioned earlier bioturbation could be strong in muddy protected shallow depressions in the mixed plat.

Detailed investigation of modern tidal flats has been restricted for some time to one area, the North Sea coast of Germany and the Netherlands. Thus in ancient tidal flat sediments this mixed flat zone has not been recognized. Tidal flat sediments were referred to as intertidal, high tidal flat or low intertidal (Raaf and Boersma, 1971; Klein, 1970; Singh, 1968).

The mixed flat deposits in the Rome Formation are represented by the rapid alternation of laminated sandstone and shale. The position of the mixed flat, as a transition zone between the mud flat and the sand flat, causes the mixed flat to contain features representative of both zones. From the mud flat, the red shales and sandstones; from the sand flat the greenish gray and pale yellowish brown sandstone. The alternately laminated shales and sandstones in the Rome Formation comprise a range from 45 percent at Porterfield Gap (Plate 5), to 80 percent at Pine Ridge I-75 (Plate 1). Not all these beds represent the mixed flat, because laminated red shales and sandstones are also found in the mud flat environment, but when laminated red shales and sandstones alternate with greenish gray, pale yellowish brown and grayish orange shales and sandstones, they probably represent the mixed flat zone. Sediments representing the mixed flat in the Rome are exemplified by the following sequences (Appendix PR units 137 to 146 and 52 to 64; OR 49 to 55; YC 9; DC 33 to 39; BV 12 to 14; SG 28 to 31; PC 46).

Bioturbated zones in the mixed flat in the Rome are usually very thin to thin bedded. Planolites are common on the lower bedding plane of many beds. They were apparently responsible for this bioturbation. Trilobite tracks are rare in this zone of the Rome (Appendix BV unit 13).

Sand Flat

The sand flat is the zone between the mixed flat and the low-water line (Figure 56, page 110). It merges with the subtidal zone and exhibits none of the subaerial features of the high intertidal zone. On sand flats, small-scale cross-bedding of current ripple origin is common. This is usually developed in the form of herringbone cross-bedding in sections cut normal to the ripple crest axis (Reineck and Singh, 1973).

As mentioned earlier, sediments of the sand flat show reducing conditions (Thompson, 1968). When red sediments are deposited in marine waters, the hematite probably becomes either hydrated to limonite or reduced to the ferrous state and loses the red color (Dorsey, 1926).

Many of the thin to thick sandstone beds in the Rome Formation do not readily exhibit internal structures, but in thin sections or polished slabs current lamination and micro-cross bedding are abundant (Figure 25, page 66 and Figure 26, page 67). Greenish gray, light brownish gray and grayish orange sandstones of the Rome were probably deposited on sand flats and in the shallow subtidal zone. These are exemplified by the following stratigraphic sequences: Appendix PR units 147 to 153; DG 40/8; NB 23; PH 25 and DR 4. These units are referred to in plates 1 to 5 as representing beach to shallow subtidal environment. Sandstones of this zone are well sorted because mud is winnowed from these sediments by the continuous reworking by waves.

Bioturbation and trace fossils are not common in this environment. Sediments accumulating under conditions of high current velocities are characterized by a shifting bottom, containing little mud and organic matter. This environment is unfavorable for deposit feeders which disturb the sediment and leave their traces in it. The instability and low organic content of these substrates result in bottom communities dominated by suspension feeders (Purdy, 1964). The Skolithos zone in the Rome represents such an environment on the sand flat. The organism which left the vertical burrows was probably a filter feeder which used the burrow as a dwelling. Skolithos occur in quartzitic sandstone and sandy dolomite (Appendix PR units 129; OR 61; YC 38, 16, 17; NB 13; BV 31; SG 10 and PG 55). In all these sections, the Skolithos zone occurs at the top of the formation, in units which are coarser than the rest of the section. This coarsening upwards represents a transgressive episode in Rome deposition.

Tidal Flat Gullies

Within the intertidal zone channels are branched landward. The meandering channels and gullies in the tidal flat are eroded usually by ebb currents, and the depth of these channels depends upon the tidal range; with currents of a high tidal range eroding deeper channels than the currents of low tidal range. The depth of these channels ranges from tens of centimeters at the beach to 4 or 5 meters in the mud flat zone landward (Thompson, 1968).

The sediment of channel fill is generally of a different nature than the surrounding sediments. Channel fill sediment is usually sandy (Reineck and Singh, 1973). According to McKee (1957) channels on tidal flats are filled up by asymmetrical steeply inclined layers. These inclined layers are produced by diagonally passing currents. When the tidal flats are still under water, and flow of water is controlled more by difference in water levels than by surface morphology, such diagonal filling of channels is commonly observed. The steeply inclined accretion layers when covered by horizontal beds of tidal flats, appear as cross-bedded units.

Perfectly preserved tidal flat gullies in the Rome are rare, because such features are not well preserved on a tidal flat (Reineck and Singh, 1973). Sediments of the tidal flat gullies in the Rome are represented by clean coarse grained sandstone (Appendix, PR unit 5), alternate coarse quartz sand and glauconitic sandstone laminae with red mud (Appendix, OR unit 58), and alternate laminae of lithoclasts; intraclasts, coarse quartz, glauconite pellets and organic debris (Appendix, SHG unit 32). The laminae in these gullies have a steep dip at the bottom and become nearly horizontal at the top (Figure 59).

Sediments of the tidal gullies in the Rome differ completely from the underlying and overlying sediments. At the Oak Ridge section the underlying sediments are grayish red, fine grained, very thin bedded sandstone, while sediments above the gully are dark greenish gray laminated shaly sandstones. At Pine Ridge I-75 the gully is underlain by grayish red very fine grained sandstone. Sediments of the tidal flat gully at Shooks Gap are represented by a heterogeneous mixture of well rounded hematitic lithoclasts, intraclasts, coarse quartz, well rounded glauconite pellets superficial ooids, and trilobite, brachiopod and echinoderm fragments all in a dolomitic matrix (Figures 60 and 61). The organic debris and glauconite pellets indicate that these sediments were washed by

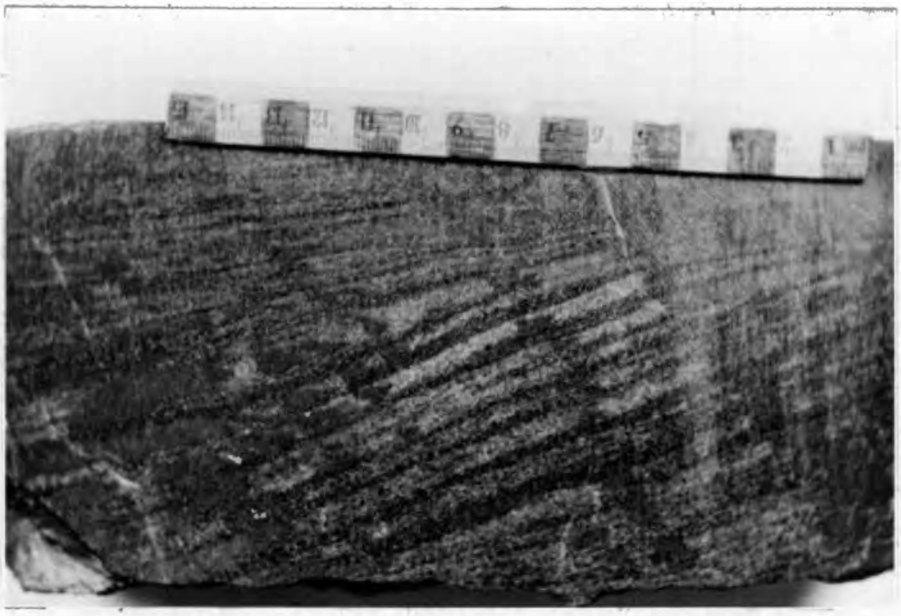

Figure 59. Inclined layers of clean quartz sandstone (light) and glauconitic sandstone (gray) with red mud (dark gray) representing a channel fill, from Oak Ridge, unit 58, cm. scale.

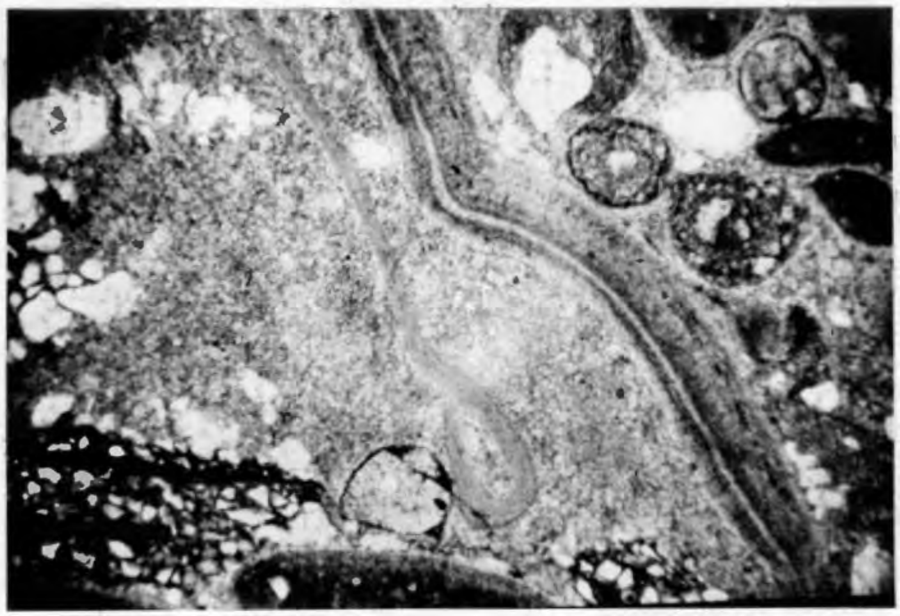

Figure 60. Photomicrograph of channel fill showing trilobite fragments, intraclasts hematitic pebbles and ,coarse quartz in a sparry dolomite matrix, Shooks Gap, unit 32, transmitted light, 25X.

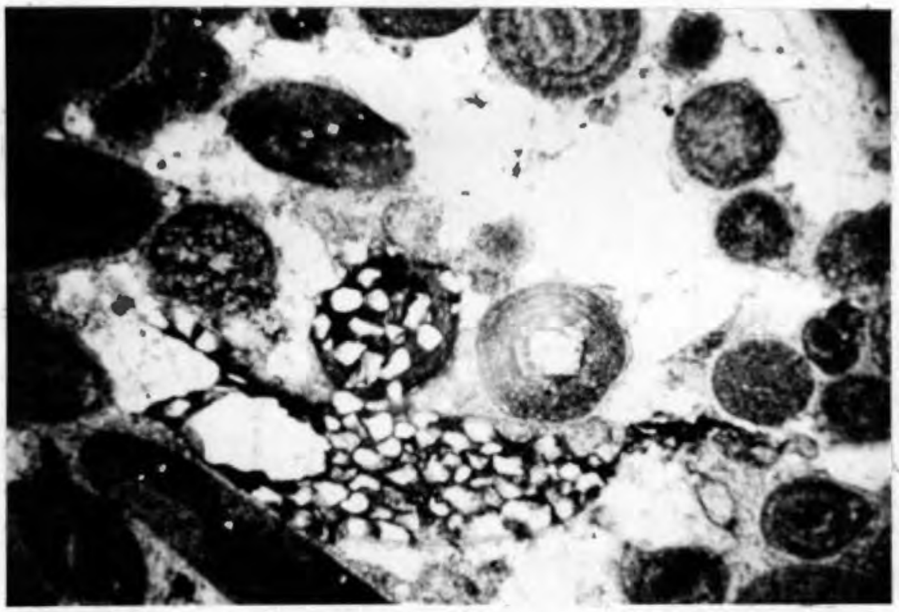

Figure 61. Photomicrograph of channel fill showing superficial ooids, intraclasts, hematitic pebbles, coarse quartz in a sparry dolomite matrix, Shooks Gap, unit 32, transmitted light, 25X.

waves on the tidal flat from the subtidal zone. Intraclasts which are rounded and coated with micrite could have been formed either by submarine erosion caused by storm waves or wave activity tearing dessicated carbonate flakes on the tidal flat (Folk, 1959). Superficial ooids were formed in this environment, while hematitic lithoclasts and coarse quartz grains which are land derived were washed into the tidal channel.

The tidal flat gully at the Oak Ridge section has a flat top and a concave bottom. It is about 3 m wide and 15 cm maximum depth. The channel at Pine Ridge seems to be larger, but its shape could not be determined because the unit believed to be a gully deposit is partially covered.

Another type of channel fill has been recognized at Young Creek (Appendix, YC unit 26/2). It represents horizontal layers of laminated shale and sandstone in a channel 2 m wide and 20 cm maximum depth. The surrounding sediments are grayish red, thin to medium bedded, very fine-grained sandstone. According to McKee (1957) horizontal layers are common in channels which are not submerged; streams deposit sediments in a channel bottom because of either an increase in sediment load or decrease in stream velocity indicating rather rapid deposition.

Sediments of tidal flat gullies are limited vertically and horizontally, thus, their position in the Rome section is of no stratigraphic significance although most of the examples described except the one at Pine Ridge I-75, occur close to the top of the sections.

IV. LAGOON

Lagoon is the zone between mean low tide landward and a barrier beach or island seaward similar to those along the present Texas coast.

The lagoon environment in the Rome is reprsented by the oolites in Porterfield Gap and Young Creek section (Appendix PG unit 60; YC unit 12). Superficial, single nucleate and composite ooids formed in such an environment. According to Carozzi (1960), composite ooids form in quiet environments which become occasionally turbulent. The ooids in such an environment are not mature or well sorted. Freidman (1962) and Rusnak (1960) reported that such ooids are forming in the hypersaline Laguna Madre along the south coast of Texas.

The lagoonal oolites in the Rome have abundant composite ooids and glauconite pellets, while lithoclasts are common (Figure 62). Laminated siltstone above an erosional surface within the oolites, indicate that the oolites formed in a very shallow lagoon close to shore are seen in Figure 63.

Another indicator of a lagoonal environment is the abundance of glauconite in the Rome lithology. Glauconite forms only in reducing marine environments (Porrenga, 1967; Millot, 1970), while its presence in laminated and micro cross-bedded red sandstones in the Rome, indicates that it was transported from a subtidal environment to the tidal flat.

According to Folk (1973) the environments of deposition of both limestone and dolomite are similar. Carbonate muds accumulate in low energy environments such as lagoons, bays or supratidal flats. Intraclastic limestones and dolomites have the same environmental significance. The presence of micritic carbonates in the Rome indicates that they were deposited in quiet environments, but the presence of intraclasts suggests that these environments became turbulent occasionally. Such conditions could be found on a tidal flat where intraclasts would form as a result of desiccation and reworking by waves, or in a lagoon, as a result of

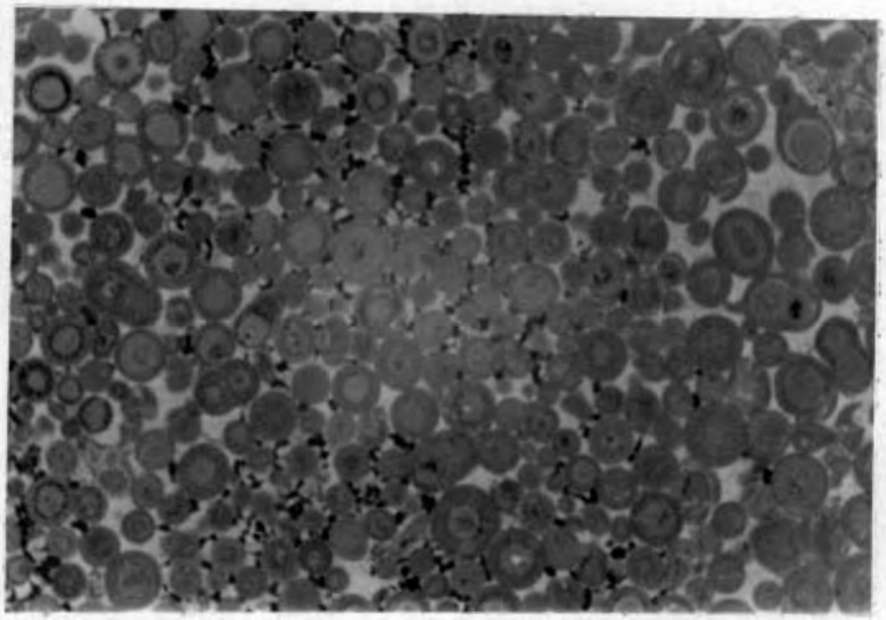

Figure 62. Photomicrograph of oolites from Porterfield Gap, unit 60, showing composite ooids, glauconite pellets, and some lithoclasts (black), transmitted light, 10X.

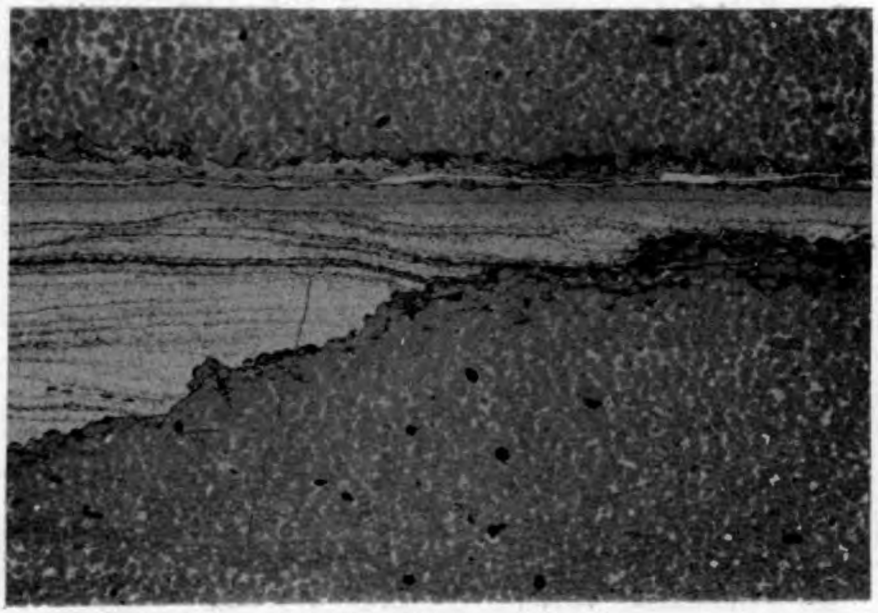

Figure 63. Photomicrograph of oolites with glauconite pellets (black) with laminated siltstone in the middle above an erosional surface, Young Creek, unit 12, transmitted light, 4X.

submarine erosion by storm waves. Where the intraclasts are angular, poorly sorted and mixed with quartz, it is probable that they formed on the tidal flat (Figure 64). Well rounded and well sorted intraclasts indicate reworking by currents for a longer time and thus suggest deposition in a lagoonal environment (Figure 65).

The position of lagoonal oolites in the Rome is close to the top of the section (Appendix PG unit 60; SG unit 8; YC unit 12). The limestones and dolomites in the Rome, are found randomly distributed throughout the Rome section alternating with sandstones and shales. Where the carbonates are associated with halite casts, mud cracks, there was no doubts as to the environment of deposition being that of a tidal flat. Intraclastic carbonates are referred to in Plates 1 to 5 as representing tidal flat to shallow subtidal due to the common occurrence of intraclasts in both environments. Examples of probable lagoonal carbonates in the Rome are reprsented by the following units in the Appendix: PG units 88, 89; YC unit 10; SG unit 8.

V. OOLITE SHOALS

The formation of typical carbonate ooids, requires water supersatured with calcium carbonate along with strong and consistent agitation, to provide proper physico-chemical conditions for precipitation around a nucleus as well as to promote formation of even laminae around the nucleus (Newell, Purdy and Imbrie, 1960). Modern ooid formation on a large scale is known only from very shallow, warm water environments with temperatures between 24^{o} and 25.7^{o} C (Lowenstam and Epstein, 1957; Bathurst, 1967). Modern oolites are forming on the Bahama Banks, the Mediterranean coast

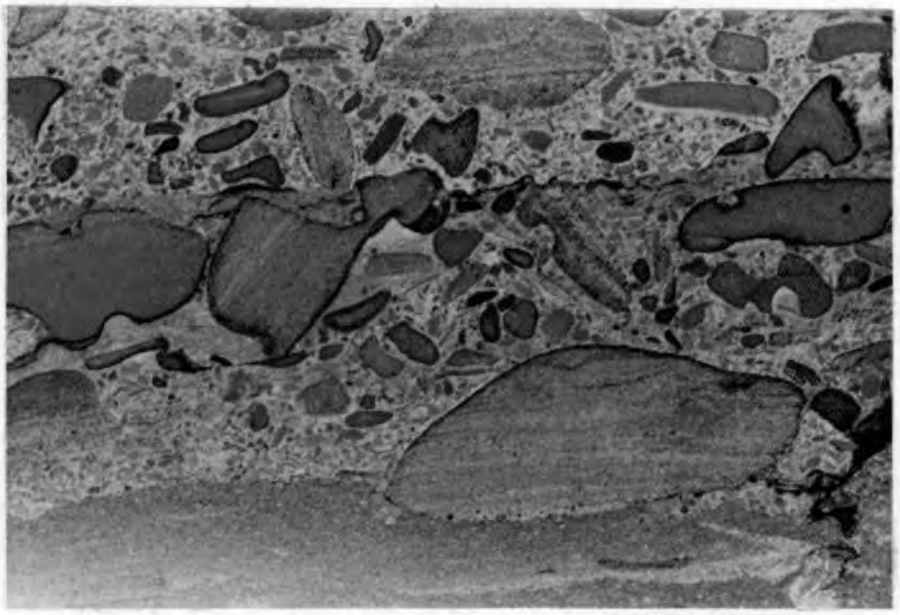

Figure 64. Photomicrograph of poorly sorted subangular to rounded intraclasts from Pine Ridge I-75, unit 118, indicating tidal flat environment, transmitted light, 4X.

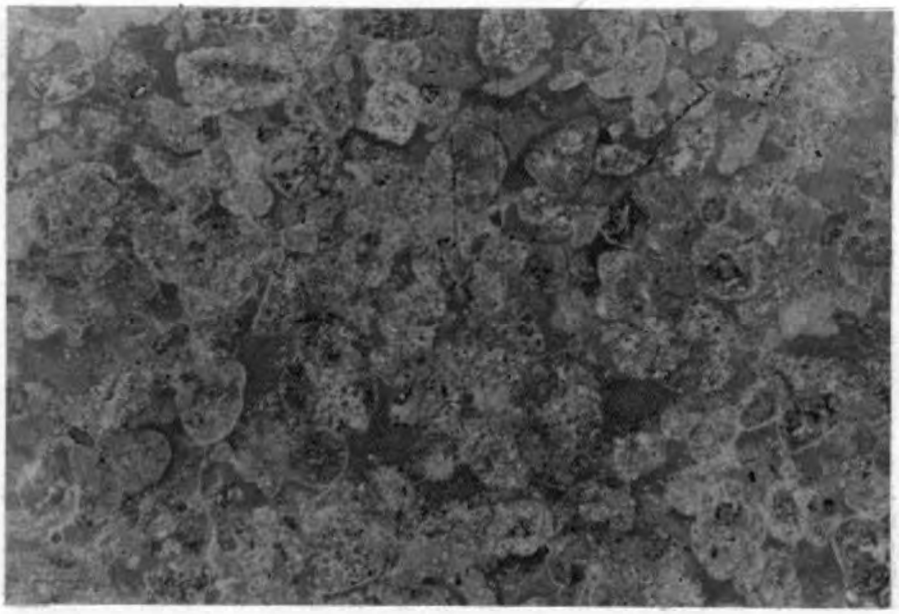

Figure 65. Photomicrograph of well sorted, well rounded intraclasts from Nelson Branch, unit 22, indicating lagoonal environment, transmitted light, 4X.

of Africa, and the south shore of the Persian Gulf (Purdy, 1961, 1963; Illing, 1954; Rusnak, 1960; Heckel, 1972). In these areas, tidal currents keep the grains in constant agitation. Deposits of oolite sand occur in the form of tidal deltas, elongate bars, barchan dunes and lobes (Ball, 1967). Depth of water overlying the Bahama shoals ranges from intertidal exposure at low tide to a maximum of 3 m (10 feet) (Purdy, 1960).

In the Rome Formation, Bahaman type oolites are found in the Pine Ridge I-75 and Oak Ridge sections (Appendix PR unit 126, OR unit 56). The ooids are mature with many concentric laminae, many with glauconitic nuclei; they are well sorted and interlaminated with well rounded glauconite pellets (Figure 66). Oolite shoals in the Rome were not extensive vertically or hotizontally; the medium bedded oolite unit at Pine Ridge I-75 wedges out in the Young Creek section where it is 7.5 cm thick (Appendix, YC unit 12).

According to Purdy (1960) there are many places along the barrier rim of the Bahama Banks where oolite deposits are absent. The oolite shoal at South Cat Cay and Brown Cay occurs as a single ridge 1 to 3 km (0.63 to 1.9 miles) wide in which the long axis of the ridge is oriented approximately normal to the direction of tidal flow; while at the head of the Tongue of the Ocean, oolite shoal ridges are parallel to the direction of tidal flow. The oolite shoals of the Rome were found only along strike in the Pine Ridge belt, which indicates that the long axis of the oolite ridge was perpendicular to the direction of tidal flow. The oolite zone is absent in the Clinton section, perhaps as a result of faulting, or to the fact that oolite shoals are not extensive areally.

Although oolites occur at Sharp Gap and Porterfield Gap about 60 m below the top of the Rome in both localities (Appendix, SG unit 8, PG unit 60), they differ from the oolites at Pine Ridge. They are slightly older

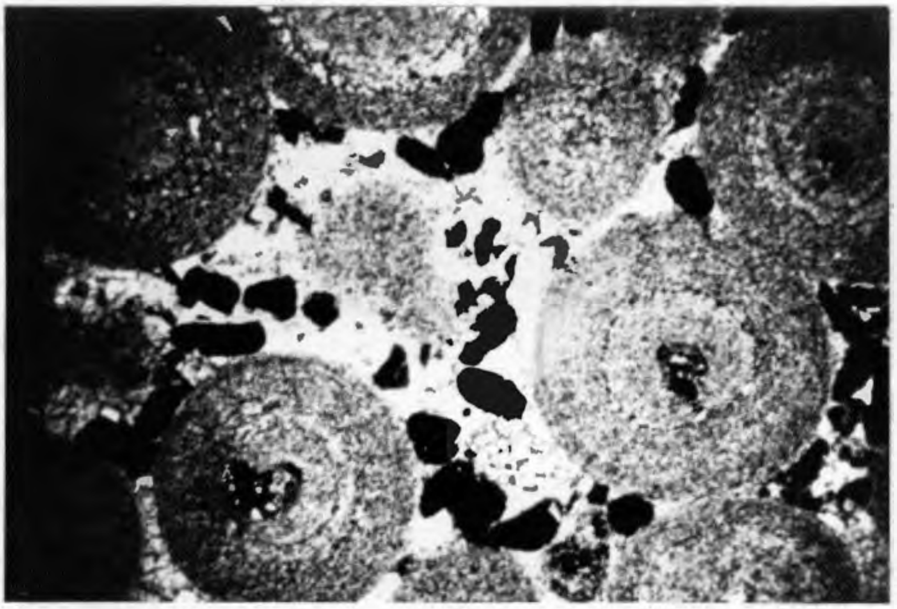

Figure 66. Photomicrograph of "Bahaman-type" oolites with glauconite pellets (black) some form the nucleii of ooids; the oolites are dolomitized, Pine Ridge I-75, unit 126, transmitted light, 25X.

and represent a lagoonal environment. Because the Rome Formation was deposited in a transgressive sea over a gently sloping surface, the alignment of Rome sections in Plate 6, indicates that the oolite zones are not contemporaneous, but represent recurring conditions suitable for the formation of ooids as the Rome sea transgressed westward. Characteristics of the different environments in the Rome are summarized in Figure 67.

VI. HORIZONTAL AND VERTICAL SEQUENCES IN THE ROME

Introduction

The horizontal sequence in a tidal flat represents gently inclined, laterally associated depositional zones which may be deposited one above the other in a transgressive sequence. The tidal flat represents a transitional zone between the continental deposits landward and marine deposits seaward, where it is associated with coastal sediments. The tidal flat sediments are differentiated into supertidal deposits, mud flat, mixed flat, sand flat and subtidal deposits. According to Reineck (1972) a transgressive sequence on a tidal flat shows from top to bottom the following sediments:

1. Sand flat deposits
2. Mixed flat deposits
3. Mud flat deposits
4. Brackish or fresh water clay
5. Peat
6. Older sediments

In a regressive sequence, the order is reversed with peat at the top and sand flat deposits at the bottom. In many cases of ancient and modern tidal flats, the above sequences may not be fully developed (Thompson, 1968; Klein, 1970; Raaf and Boersma, 1971). Reineck (1972) indicated that

Environment	Biogenic and Sedimentary Structures	Lithology
Supratidal	Halite casts, mud cracks. Ripple marks, Birdseye and algal laminae in dolomite. Rare: *Scoyenia*, *Cruziana* and *Rusophycus*. Bioturbation is rare to absent.	Grayish red shale, siltstone very fine grained sandstone. Fine dolomite. Beds mostly laminated to very thin bedded.
Mud flat	Mud cracks, ripple marks tidal balls. Abundant: *Rusophycus*, *Cruziana*, *Planolites* Bioturbation: strong	Grayish red shale, siltstone very fine grained sandstone. Shale is abundant.
Mixed flat	Flaser, lenticular and wavy bedding, alternate laminated sand and shale. Occasional *Planolites*: mud cracks common. Bioturbation: less than mud flat.	Alternate grayish red sandstone and shale and greenish gray, brownish gray shales and sandstone. Beds are laminated to thin bedded with medium to thick bedded sandstone tongues of the sand flat.
Sand flat	Micro cross-bedding, current laminated *Skolithos* abundant *Planolites* subcommon Bioturbation: weak	Greenish gray, pale yellowish brown thin to thick bedded fine grained sandstone, well sorted. Shale nearly absent.
Tidal Flat Gullies	Steeply dipping alternate laminae, sometimes horizontal. Cross-bedding *Planolites*: subcommon Bioturbation: absent	Coarse to very coarse quartz, glauconite, lithoclasts, intraclasts and trilobite fragments, transported burrow casts, all of which differ from the surrounding sediments. Channel is lens shaped.
Lagoon	*Rusophycus*, *Bergaueria*, *Phycodes* are common.	Superficial and composite ooids, glauconite, greenish gray shale and siltstone. Intraclastic and fine limestones and dolomites.
Oolite Shoal	Cross-bedding	"Bahaman type" oolites, glauconitic sandstone.

Figure 67. Characteristics of the different environments in the Rome.

major controlling factor in developing the sequence is the availability of appropriate sediments.

Pine Ridge Belt

The Rome Formation as a whole represents a transgressive sequence which coarsens upward. Within this general sequence there are transgressive and regressive phases within the tidal flat zone. Because the Pine Ridge I-75 (PR) section is the best exposure in the Pine Ridge belt, it will be used to illustrate transgressive and regressive sequences within this belt.

The bottom of the Rome section at Pine Ridge I-75, units 1-87 (Appendix) is made up of red shale, siltstone, very fine-grained sandstone with occasional thin to medium bedded limestone and dolomite. The red beds, mud cracks and halite casts represent the supratidal and mud flat zones in the Rome, PR units 1, 9, 35, 70 and 86 (Appendix) represent a supratidal zone as indicated by the presence of halite casts, Scoyenia, birdseye structure (in dolomite) and the absence of bioturbation. The rest of the units represent the mud flat deposits with occasional intertonguing of mixed flat sediments (Appendix PR units 37, 43, 45). This part of the Rome section (units 1 to 87) represents a regressive sequence with sediments prograding seaward. Thick intraclastic limestone units 88 and 90 (Appendix PR) and the intervening shale (unit 89) probably accumulated in a lagoon environment and indicate a transgressive sequence. Units 91 to 108 (Appendix PR) are made up of olive gray, dusky yellow and greenish gray shale, siltstone and sandstone. The occurrence of alternate laminated shale and sandstone, flaser bedding and occasional bioturbation indicate a mixed flat zone. The above sequence contains units of grayish red shale and sandstone, representing tongues of the mud flat (Appendix PR units 98, 100/3, 103/3). Tongues of the sand flat are represented by greenish gray sandstone (Appendix PR unit 92). Thin bedded dolomites and limestones occur more frequently between units 108 and 124. This part of the section contains red beds alternating with greenish gray sandstone and shale. The sequence is composed of alternating layers of mixed flat deposits and lagoonal carbonates that indicate transgressive and regressive phases within the mixed flat zone. Units 125 and 126 are made up of coarse, greenish black glauconitic sandstone overlain by oolites that represent marine shoals. There is no doubt that this zone which is 1 m (3 feet) thick, represents a transgressive phase. Units 127 to 134 contain the Skolithos zone; frequent coarse sandstone units represent the beach or low sand flat environment; while transported burrow casts indicate a channel deposit. Most of the beds above the oolite zone are greenish gray sandstone and shaly sandstone with occasional grayish red sandstone, probably tongues of the mixed flat. This sequence indicates the continued transgression which started when the oolites were deposited. Units 135 to 145 are made up of very thin to thin bedded greenish gray sandstone and laminated shale with grayish red laminated sandstones and shales. Bioturbation is common in both grayish red and greenish gray beds. This sequence represents an intertonguing of mud flat and sand flat sediments in the mixed flat zone. Thus reflecting a short regressive phase. Units 146 to 153 are characterized by the dominance of greenish gray and pale yellowish brown thin to medium bedded sandstone, while shale is rare at the bottom and absent at the top. This sequence represents the sand flat zone. The different sequences in the Pine Ridge I-75 section are summarized in Figure 68.

Bullrun Ridge Belt

The Bullrun Ridge sections show a general transgressive sequence from bottom to top, with red beds more abundant at the bottom and absent at the top. The Diggs Gap section (DG) is used here to represent the Bullrun Ridge belt. The dolomitic sandstone, dolomite, and greenish gray quartzitic sandstone (Appendix DG units 1 to 3) probably represents a shallow lagoon and sand flat zone, with a unit of grayish red shale (unit 2) representing a tongue of the mud flat, but the whole sequence indicates a transgressive phase. Units 4 to 10 (Appendix DG) are made up of grayish red sandstone and shale alternating with greenish gray sandstone and shale. This sequence is indicative of a mixed flat zone. Units 11 to 18 (Appendix DG) are made up of grayish red shale and very fine-grained sandstone. This sequence includes, tidal balls, and abundant Rusophycus and Cruziana and thus indicates the mud flat zone. Alternate units of laminated grayish red and greenish gray sandstone and shale, with occasional bioturbated units (Appendix DG units 19 to 38) indicate a mixed flat zone with tongues of the mud flat and sand flat zones. Units 39 to 40 (Appendix DG) are made up of light olive gray shale overlain by greenish gray and pale yellowish brown sandstone. The shales probably accumulated in a lagoonal environment, while the sandstones represent the sand flat zone. The different phases in Diggs Gap are summarized in Figure 69.

Units	Thickness (m)	Zone
146-153	18.61	Sand flat
135-145	24.01	Mixed flat
127-134	15.79	Sand flat
125-126	1.02	Oolite shoal
109-124	28.97	Lagoon & mixed flat
91-108	47.87	Mixed flat
88-90	16.98	Lagoon
1-87	145.00	Supratidal & mud flat

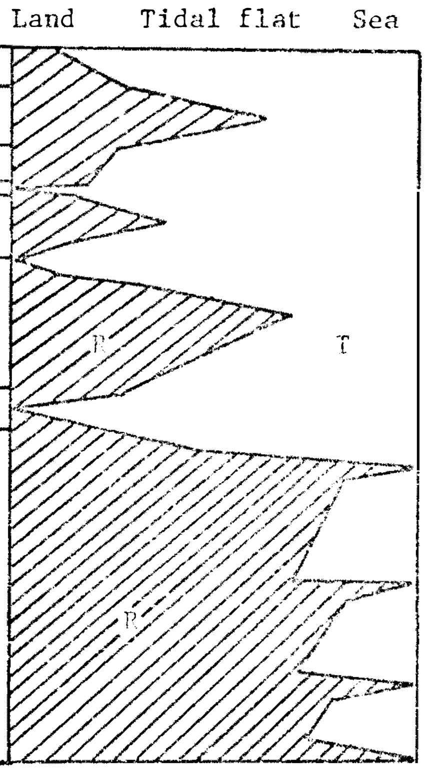

Figure 68. Transgressive (T) and Regressive (R) sequences in the Pine Ridge I-75 section. Vertical scale 1:3000.

Units	Thickness (m)	Zone
39-40	22.25	Laggoon - Sand flat
19-38	43.90	Mixed flat
11-18	20.40	Mud flat
4-10	[illegible]	Mixed flat
1-3	11.73	Lagoon - Sand flat

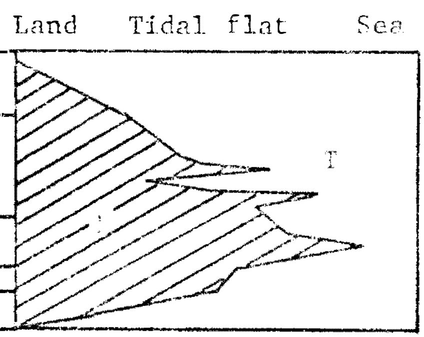

Figure 69. Transgressive (T) and Regressive (R) sequences in the Diggs Gap section. Vertical scale 1:3000.

Beaver Ridge Crippen Gap (CG)

Like the other exposures, the Crippen Gap section shows a general transgressive sequence from bottom to top. Dolomite and dolomitic sandstone with a Skolithos horizon (Appendix CG units 1 to 5) represent lagoonal and sand flat zones; the grayish red laminated to thin bedded sandstone (unit 3) is a tongue of the mud flat zone. Units 6 to 7 (Appendix CG) contain greenish gray alternate laminated sandstone and shale, with sandstone being dominant. These deposits indicate a mixed flat zone. Units 8 to 27 (Appendix CG) are made up of grayish red sandstone and shale. Mud cracks are common, and together with Planolites and Rusophycus indicate a mud flat zone. Within this sequence there are two horizons representing the supratidal zone, indicated by the presence of Scoyenia (unit 15) and conglomerates (units 23 to 25). Units 28 to 35 (Appendix CG) are made up of greenish gray sandstone and shale with sandy dolomite in the middle containing a prominent Skolithos zone. Bergaueria at the top of the section in unit 35 suggest marine conditions (Crimes, 1970). Thus the whole sequence represents lagoonal and sand flat environments, with the exception of a medium bedded grayish red sandstone bed with Scoyenia (Appendix CG unit 33) that represents a supratidal tongue, probably on a barrier island. The different phases in the Crippen Gap section are summarized in Figure 70.

Sharp Gap (SG)

The Sharp Gap exposure similar to the Pine Ridge, Diggs Gap and Crippen Gap section, has no red beds at the top of the section, indicating a general transgressive sequence upwards. The beds overlying the Saltville

Units	Thickness (m)	Zone
28-35	24.85	Lagoon - Sand flat
8-27	40.60	Mud flat
6-7	8.95	Mixed flat
1-5	16.95	Lagoon - Sand flat

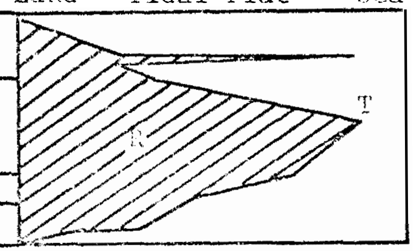

Figure 70. Transgressive (T) and Regressive (R) sequences within the Crippen Gap section. Vertical scale 1:3000

fault are, from bottom upward, sandy dolomites, grayish red, laminated to very thin bedded sandstone, and intraclastic and oolitic dolomite; this sequence found in units 1 to 8 (Appendix SG) represents a lagoonal environment, while the red beds indicate a tongue of the mud flat zone. Units 9 and 10 are made up of light olive gray sandstone at the bottom becoming gradually grayish red at the top. Skolithos in the greenish gray sandstone indicate a high sand flat zone, because above the Skolithos, Scoyenia in red sandstone represent a tongue of the supratidal zone (Appendix SG unit 11). The rest of the section (Appendix SG units 12 to 48) is made up of greenish gray, grayish brown and moderate yellowish brown sandstone and shale alternating with grayish red sandstone and shale. The alternating laminated shale and sandstone, flaser bedding and occasional mud cracks indicate a mixed flat zone with occasional mud flat tongues. Tongues of the sand flat zone are represented by thin to medium bedded sandstones (Appendix SG units 44/4, 41, 39). The different phases in the Sharp Gap section are summarized in Figure 71.

Porterfield Gap (PG)

The Porterfield Gap section more than any other section in the study area, shows the repeated occurrence of halite casts representing the supratidal zone (Appendix PG units 8, 22, 24, 42, 47, 54, 63). The bottom of the section (units 1 to 31) represents a regressive sequence with abundant halite casts and mud cracks in red beds, indicating supratidal and mud flat environments; the dolomites which are interbedded with red beds (Appendix PG units 3, 11, 12, 13, 17, 18, 19) belong to the supratidal and mud flat zones, as indicated by the halite casts and mud cracks

Units	Thickness(m)	Zone
12-48	52.20	Mixed flat
11	2.12	Supratidal
9-10	4.98	Sand flat
1-8	18.30	Lagoon

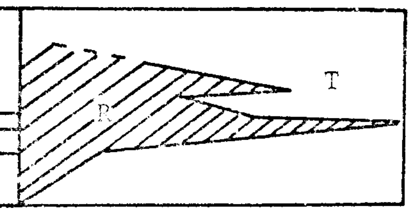

Figure 71. Transgressive (T) and Regressive (R) sequences within the Sharp Gap section. Vertical scale 1:3000

below and above the dolomites. Units 32 to 38 are made up of thick bedded dolomite and very thick bedded quartzitic sandstone which accumulated in a sand flat, or subtidal zone while the dolomites were deposited in a quiet lagoon. The grayish red, very fine-grained sandstone in unit 39 represent a thick sequence (27 m) of mud flat deposits. Units 40 to 42 are made up of sandy dolomite, quartzitic sandstone and grayish red, laminated sandstone and shale with halite casts and mud cracks, all of which are characteristic of the supratidal zone. A mixed flat zone is illustrated by a sequence of alternate greenish gray laminated sandstone and shale which is overlain by sandy dolomite and light grayish orange sandstone (Appendix PG units 43 - 45) representing tongues of the sand flat and lagoonal sediments. Unit 46 which overlies the covered interval is made up of greenish gray laminated sandstone and shale indicating a mixed flat too. Unit 47 is made up of grayish red silty sandstone with mud cracks and halite casts showing another supratidal zone. This zone is overlain by sandy dolomite, dolomitic sandstone, grayish red sandstone, pale brown quartzitic sandstone and dolomite (units 48 to 52). Tongues of the sand flat are shown by the presence of quartzitic sandstone and Rusophycus in unit 51. The grayish red sandstone and dolomite with halite casts in units 53 and 54 indicate that the whole sequence of units 47 to 54 belong to the supratidal zone. The units above this zone are made up of dolomite, sandstone, dolomite sandstone and alternating grayish red sandstone and shale. One characteristic of these units (Appendix PG units 55 - 59) is the presence of trace fossils such as Skolithos and Planolites which are absent from supratidal environments. Thus this sequence represents a lagoonal environment with tongues of the sand flat and mud flat zones. The top of unit 59 which contains large Rusophycus and an oolite zone (unit 60) together with pale brown sandstone and glauconitic, greenish gray, shaly sandstone (units 61 and 62) represent a lagoonal zone. This zone is overlain by red beds with halite casts, mud cracks and rain prints (unit 63) all of which are indicative of the supratidal zone. The different phases at Porterfield Gap are summarized in Figure 72.

From the above transgressive and regressive sequences, it is clear that the sea remained very shallow over the Rome tidal flats as sedimentation kept pace with slow subsidence.

VII. CORRELATION OF TRANSGRESSIVE AND REGRESSIVE SEQUENCES

The Rome sediments were deposited in environments ranging from the supratidal zone to the shallow subtidal zone. In an ideal transgressive sequence, supratidal and mud flat deposits are overlain by mixed flat deposits which grade upwards into sand flat and shallow subtidal deposits (Figure 73). This sequence reflects the horizontal position of these zones across a tidal flat with a uniform slope. However, the width of the different zones on the tidal flat, and the thickness of deposits in a zone, in a transgressive or regressive sequence depend upon the local topography. Sand flat deposits may overlie supratidal deposits in a transgressive sequence (Thompson, 1968). Such abrupt changes in sedimentation could be seen in the Pine Ridge I-75 and Porterfield Gap section (Figure 68, page 138 and Figure 72) where lagoonal deposits overlie supratidal deposits and visa versa.

Units	Thickness	Zone
63	5.00	Supratidal
59-62	11.48	Lagoon
55-59	29.38	Sand flat
47-54	25.50	Supratidal
46	14.40	Mixed flat
Covered	61.20	________
43-45	9.32	Mixed flat
40-42	14.80	Supratidal
Covered	13.30	________
39	27.30	Mud flat
32-38	44.90	Lagoon - sand flat
1-31	77.40	Supratidal and mud flat

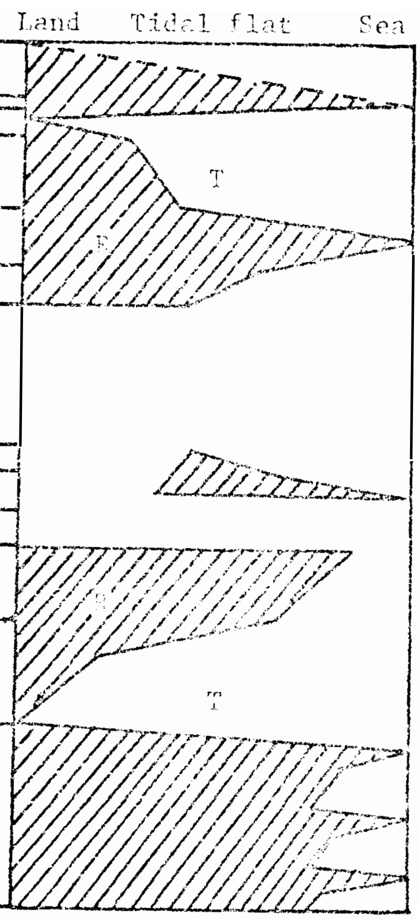

Figure 72. Transgressive (T) and Regressive (R) sequences within the Porterfield Gap section. Vertical scale 1:3000

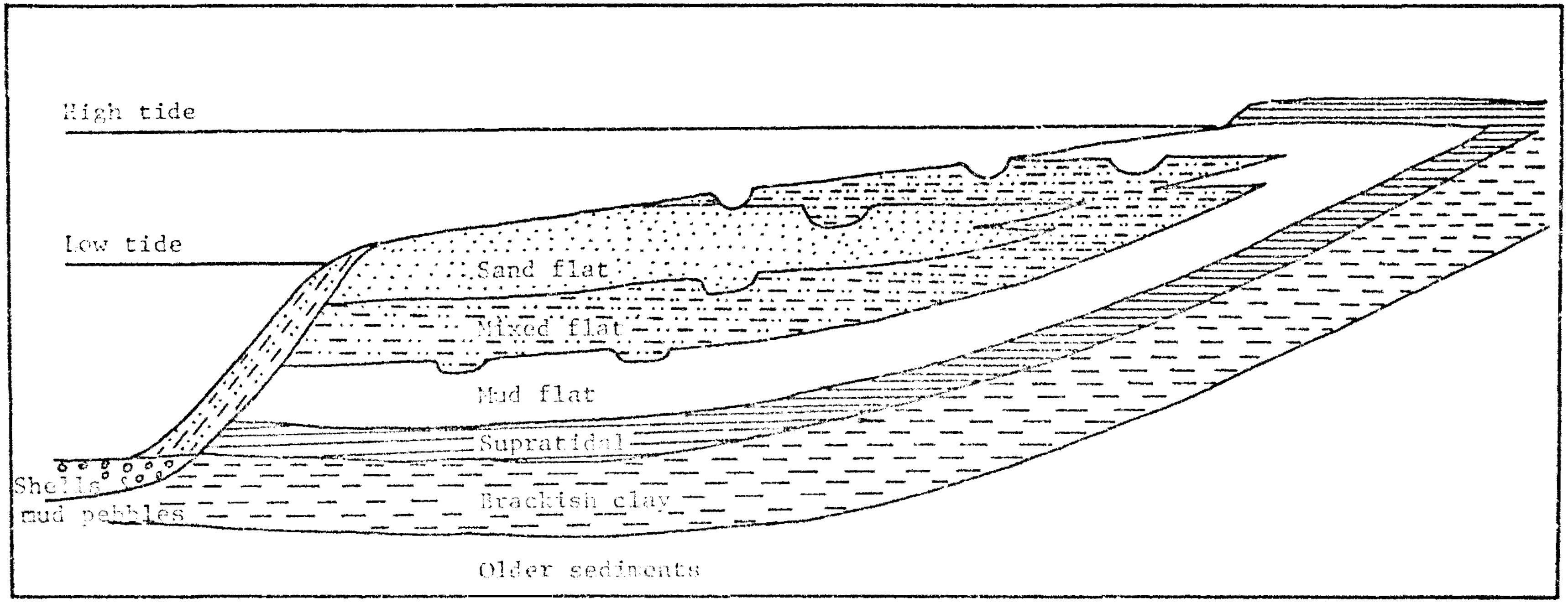

Figure 73. Ideal vertical sequence of transgressive and regressive deposits in a tidal flat. (Modified from Reineck, 1973).

The correlation of transgressive and regressive sequences in the different Rome sections across strike (Figure 74) indicates that the sequences at the bottoms of the Pine Ridge and Porterfield Gap sections represent prograding deposits of the mud flat and supratidal zones (Appendix PR units 1 to 87, PG units 1 to 31). Although prograding (regressive) and retrograding (transgressive) deposits alternate at the top of the sections (Figure 74) there is a general transgressive trend above the following units: PR unit 87, DG unit 18, CG unit 27, SG unit 11 and PG unit 54 (Figures 68 to 72). Although individual beds cannot be traced across the strike in the Rome Formation, transgressive and regressive sequences based on environmental interpretation can be correlated successfully, taking into consideration the local environments in each belt. The alignment of these sequences shows that the contact between the Rome and the Pumpkin Valley Shale is a gently sloping surface. When the palinspastic distance between the Pine Ridge and Bays Mountain is considered, it becomes clear that the Rome deposits are younger westward as the Rome sea advanced in that direction.

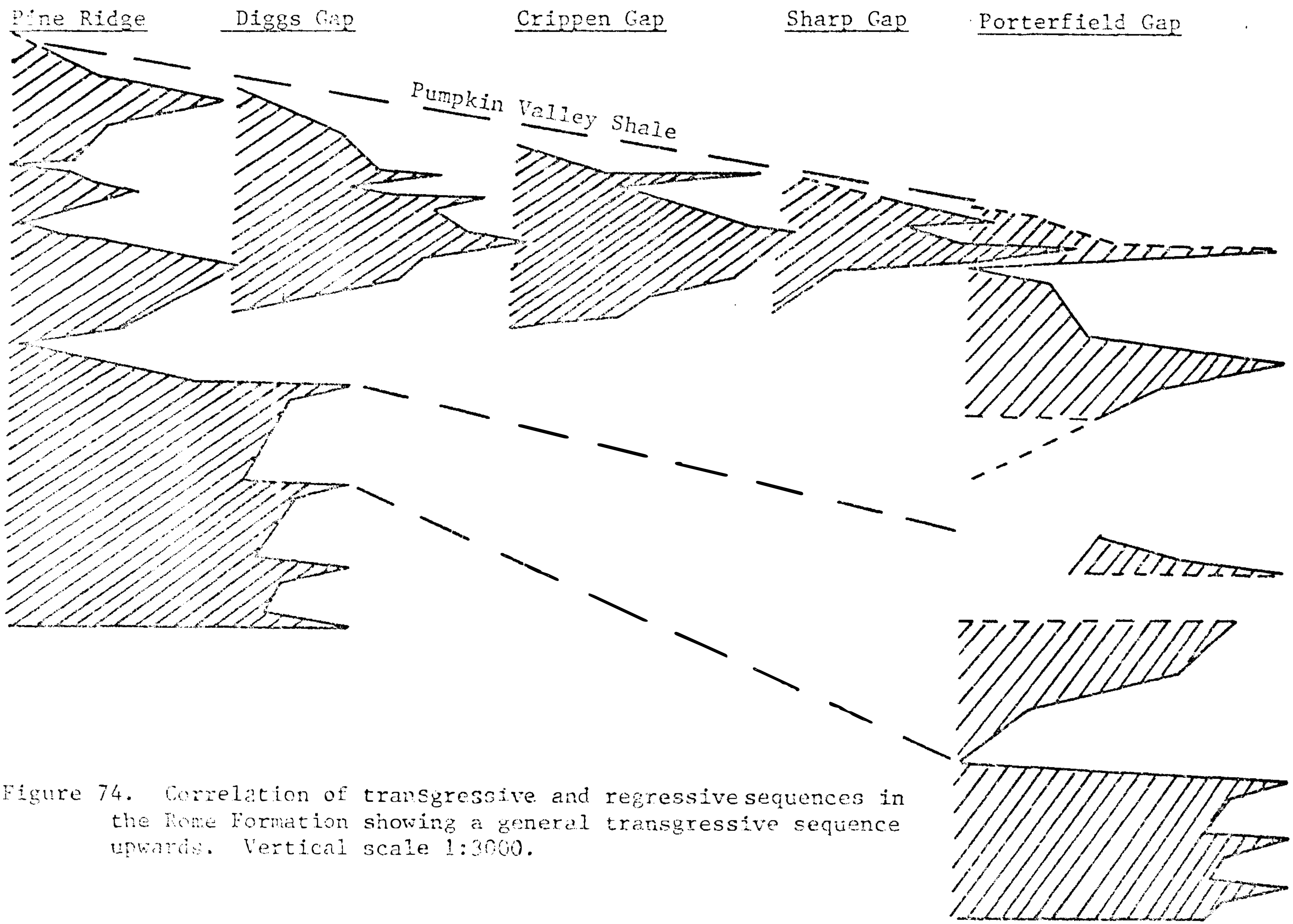

Figure 74. Correlation of transgressive and regressive sequences in the Rome Formation showing a general transgressive sequence upwards. Vertical scale 1:3000.

CHAPTER VII

CORRELATION OF THE ROME FORMATION

I. INTRODUCTION

One of the main objectives of this study is the correlation of the Rome Formation parallel to and across strike. Within the study area, units of the Rome can be traced easily along strike for long distances. The detailed study of the Rome stratigraphy revealed the presence of marker beds. These beds or sequences could be lithologically correlated for more than 40 km (25 miles) in one strike belt and for shorter distances in others. Correlation across strike was achieved through the tracing of the oolite zone and the Skolithos zone above it. These two zones which are not continuous from southeast to northwest mark the upper part of the Rome Formation. These two zones in the different belts are not contemporaneous, but represent similar environments at those levels.

II. PINE RIDGE BELT

Four sections were studied along Pine Ridge (Plate 1). Because the bottom of the formation is faulted out by the Whiteoak Mountain fault, only the upper part can be correlated. In fact, there is an entire sequence of beds which can be traced along strike in this belt. The oolite zone which occurs in all the sections except Clinton was chosen as the datum plane. This zone is followed upwards by a sequence of units (Table 6) which were traced over a distance of more than 40 km (25 miles) from Pine Ridge I-75 in the northeast to Young Creek in the southwest. These units from bottom upward consist of medium-to coarse-grained

Table 6. Sequence of units which can be traced along the Pine Ridge belt. For more detail see Appendix.

	Pine Ridge I-75 Unit	Clinton Unit	Oak Ridge Unit	Young Creek Unit
Transported burrow casts	134	--	70	22
Bioturbated	132	--	63	18
Skolithos zone	127/1	--	61	16 and 17
Coarse sandstone	127/3	11	58	15
Oolitic zone	126	--	56	12

quartz sandstone, Skolithos zone, bioturbated horizon and transported burrow casts (Figure 75). This sequence of units indicates that the Rome Formation in Pine Ridge in the study area can be correlated along strike.

There is a problem in the Pine Ridge belt, as to where to draw the boundary between the Rome and the Pumpkin Valley Shale. At Pine Ridge I-75 there is a prominent sandstone unit 1.77 m thick (Appendix PR unit 153) 60 m above the oolite zone. This unit marks the top of the Rome here, but at Oak Ridge the top is covered and at Young Creek the top sandstone unit is not as prominent as that at Pine Ridge I-75. Because the oolite zone occurs in the above sections and was used as a datum plane, the top of the Rome at Oak Ridge and Young Creek was drawn 60 m (200 feet) above the oolite zone.

III. BULLRUN RIDGE BELT

The Bullrun Ridge sections, compared to other Rome sections, are the most faulted, and many layers represented in the sections are folded. Although this deformation complicates the stratigraphy, units within the Rome in this belt were traced for a distance of 20 km (12.5 miles) from Diggs Gap in the northeast to Pumphouse Road in the southwest (Plate 2). The Diggs Gap, Nelson Branch and Pumphouse Road sections have some units which are similar in appearance, but there is no sequence of units like that in the Pine Ridge belt. Tidal balls are found in the Pumphouse Road (unit 3) and Diggs Gap sections (unit 11) but they are absent in the Nelson Branch section. Abundant Rusophycus and Cruziana in the red beds of unit 10 are similar to those at Diggs Gap unit 11 and are considered to represent the same stratigraphic horizon. Thick bedded sandstone

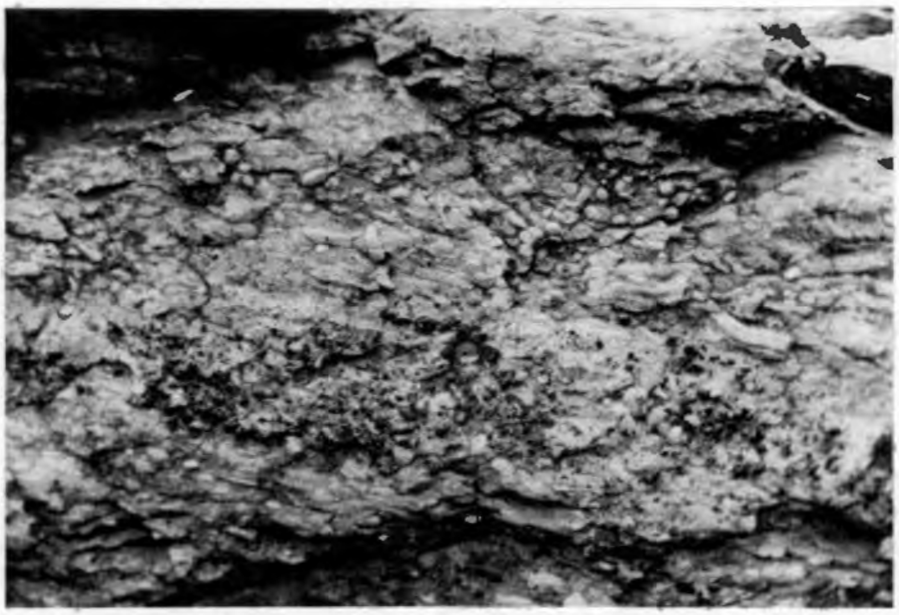

Figure 75. Transported burrow casts, Young Creek, unit 22, 0.5X.

units occur at the top of the three sections. At Diggs Gap the thick-bedded sandstone is found at the bottom of unit 40; at Nelson Branch in unit 23; and at Pumphouse Road it is found in unit 25. These units are the only thick-bedded sandstones at the top of these sections, indicating the same stratigraphic zone. The Copper Creek fault was used as a datum plane for the Bullrun Ridge sections (Plate 2) because there is no common stratigraphic horizon to put them at the same level. This proved to be satisfactory for the Diggs Gap, Nelson Branch and Pumphouse Road sections. At Nelson and Pumphouse Road - a distance of 12 km - two zones could be traced. In the Nelson Branch section these two zones are a 10 cm thick, bioturbated, grayish black sandstone (unit 16) and a dark gray dolomite bed 1.15 m thick unit 22. The same beds are found at Pumphouse Road, where the bioturbated sandstone in unit 20 is 10 cm thick and the dolomite bed in unit 23 is 35 cm thick.

The Dug Ridge section, although it appears to be undisturbed by folding or faulting, does not have any units which could be traced into the Pumphouse Road section 21 km to the northeast (Plate 2). The thick-bedded sandstone occurs just above the fault at the base of the section (Appendix DR units 4 and 5) instead of at the top like the other three sections. The top of the section is covered, and it is possible that there might be bedding plane thrust faults which are not readily apparent.

The boundary between the Rome and the overlying Pumpkin Valley Shale in Bullrun Ridge, was drawn above the first prominent sandstone unit below the Conasauga Shale. No oolite zone was found in any of the sections of this belt in the study area. The correlated units within this belt are summarized in Table 7.

Table 7. Correlated units in the Bullrun Ridge belt. For more detail see Appendix.

	Dug Ridge Unit	Pumphouse Road Unit	Nelson Branch Unit	Diggs Gap Unit
Thick-bedded sandstone	--	25	23	40
Dolomite bed	--	23	20	--
Bioturbated sandstone	--	20	16	--
Tidal balls, *Rusophycus* and *Cruziana*	--	3	10	11

IV. BEAVER RIDGE BELT

The Crippen Gap outcrop is the only well exposed section along Beaver Ridge. Although, this section has features similar to other Rome exposures, such as red beds, mud cracks, local dolomite beds and occasional coarse sandstone horizons, the facies across the strike are not continuous (Plate 6). No oolite zone was found in this section, but the Skolithos zone which is found above the oolite zone in the Pine Ridge belt and Sharp Gap is present. Either the oolite zone did not extend into this belt or it is faulted out. The top of the Rome was drawn above the first sandstone unit below the Pumpkin Valley Shale.

V. SHARP RIDGE BELT

The two sections measured along Sharp Ridge, Sharp Gap and First Creek are 5 km apart. Only the bottom units above the Saltville fault can be correlated. Thus this fault was chosen as a datum plane for the two sections. The dolomite units at the bottom of both sections are similar in appearance and represent the same dolomite zone cut by the Saltville fault. The sequence of beds at the bottom of the First Creek section (units 1 to 11) could be traced into units 1 to 8 in the Sharp Gap section (Plate 4). Dolomite beds 12 m above the Saltville fault at First Creek are interbedded with sandstone and shale layers, while at Sharp Gap the dolomite beds 15 m above the fault are not interbedded with clastics, indicating that carbonates intertongue with clastics parallel to strike. Upwards above the dolomite beds, the two sections have no marker beds; the First Creek section is folded and faulted and completely disturbed. The top of the Rome was drawn above the first sandstone unit below the Pumpkin Valley Shale. This happened to be about 60 m above the oolite zone in the Sharp Gap section.

VI. BAYS MOUNTAIN BELT

The lithology of the Rome at Bays Mountain differs from the other Rome belts in that carbonates are more abundant here. The carbonates are dominantly dolomites that are medium to thick-bedded, white to medium gray and occur throughout the Rome section at Porterfield Gap. Mud cracks and halite crystal casts are abundant in this section in both clastic and carbonate units. The Shooks Gap section is poorly exposed, and only the top part of the section where the oolite zone (unit 32) is found, could be correlated with that at Porterfield Gap (unit 60). The oolite zone was chosen as the datum plane since it occurs in both sections (Plate 5); the two sections are 5.6 km (3.5 miles) apart. The top of the Rome and the Pumpkin Valley Shale are covered in both sections, thus the nature of the contact between the two could not be determined. However, Rodgers and Kent (1948) found an oolite zone 53 m (177 feet) below the top of the Rome in the Lee Valley section which is in the same strike belt with Bays Mountain. Thus the boundary between the Rome and the Pumpkin Valley Shale was drawn about 60 m (200 feet) above the oolite zone in Porterfield Gap (Plate 6).

VII. CORRELATION OF THE ROME ACROSS STRIKE

As mentioned earlier there are definite marker beds within each Rome belt, but not all of these beds are correlatable from belt to belt across strike. Only the oolite and the Skolithos zones could be traced across strike, even then the two zones are not found in all the belts in the study area (Table 8). The oolite zone which ranges in thickness from 7.5 cm (3 inches) to 56 cm (22 inches) occurs 60 m below the top of the Rome Formation. At Pine Ridge I-75 the oolite zone is in unit 126; Oak Ridge, unit 56; Young Creek unit 12; Sharp Gap, top of unit 8; Porterfield Gap, unit 60, and Shooks Gap unit 32 (see Appendix). No such zone was found in the Bullrun Ridge or Beaver Ridge sections. Either it did not extend into those areas or it is faulted out.

The topmost Skolithos zone at Crippen Gap (unit 33) is about 18 m below the top of the section. This zone is found in the Pine Ridge belt (Table 6, page 147) and Sharp Gap (unit 10) 4 to 8 m above the oolite zone, while at Nelson Branch the Skolithos zone (unit 13) is 20 m below the top of the section. Where the oolite zone is missing the Skolithos zone can be used instead for correlation across strike. Thus the above two zones in the Rome Formation could be traced over a palinspastic distance of 105 km (66 miles), from Pine Ridge in the northwest to Bays Mountain in the southeast (Plate 6).

IX. AGE AND RELATIONSHIP TO OTHER FORMATIONS

Introduction

The rocks of the Valley and Ridge Province in Tennessee are cut by a series of northeast - trending thrust faults. Northwestward movement along these faults is measured in kilometers (Plate 6). The thrust sheets obscure regional facies changes by bringing rocks deposited at different times and in different parts of the Rome basin of deposition into close proximity. Within the different Rome belts the lithology remains relatively constant, but across fault belts the facies differ. In order to remove

Table 8. Correlated Skolithos and oolite zones in the Rome Formation across strike.

	Pine Ridge Unit	Nelson Branch Unit	Beaver Ridge Unit	Sharp Gap Unit	Porterfield Gap Unit
Skolithos zone	127/3	13	33	10	--
Oolite zone	126	--	--	8	60

the effect of shortening of the depositional basin by thrusting, the sections were restored to their relative position before thrusting (Plate 6) according to an unpublished structural section across the Valley and Ridge Province by Dietrich Roeder (1975).

Stratigraphic studies of the exposed Rome Formation in Tennessee are complicated because the base of the Rome is marked by major thrust faults. Key beds were established in the formation in the study area. The oolite zone at Pine Ridge, Sharp Gap and Bays Mountain, about 60 m (200 feet) below the top of the Rome, was used as a marker bed (Plate 6). The top Skolithos zone at Crippen Gap about 18 m (60 feet) below the top of the Rome, marks a distinct horizon which is common to Pine Ridge, Sharp Gap and Nelson Branch; but there is no zone in the Rome that is continuous and common to all the exposed sections and the subsurface in Tennessee.

X. ROME - CONASAUGA RELATIONSHIP

The Conasauga Group of Tennessee is composed of six alternating units of shale and limestone. The lowermost, the Pumpkin Valley Shale, consists of interbedded shale, siltstone and thin glauconitic sandy beds. The shales and siltstones are red, green and brown. The siltstone becomes more abundant towards the northwest. The other shale units, the Rogersville and Nolichucky shales are less silty but contain thin beds of limestone which are either oolitic or intraclastic. The two limestones, Rutledge and Maryville Formations, thin abruptly toward the northwest (Figure 4, page 9). The Maynardville, made up of a lower limestone and an upper dolomite, is persistent in outcrop and in the subsurface. The Copper Ridge Dolomite and its equivalent to the northeast, the Conococheague Limestone, - overlying the Conasauga Group - attain thicknesses of up to 300 m (1000 feet) and are also prominent in outcrops and in the subsurface in Tennessee (Plate 6).

A comparison of measured sections of the Rome Formation, the Conasauga Group and the Copper Ridge Dolomite and its equivalents the Concocheague shows that the Copper Ridge Dolomite is persistent in exposures and in the subsurface; hence, the top of the Copper Ridge Dolomite and its equivalents were used as a reference datum for this study (Plate 6). With the sections aligned on the top of the Copper Ridge Dolomite, it is readily apparent that the contact between the Rome and the Conasauga Group rises towards the northwest. Thus by lateral gradation the top of the Rome in the subsurface is a facies equivalent of the lower Conasauga in the Appalachian Valley in Tennessee. This indicates that the Pumpkin Valley Shale Formation is a facies equivalent to the upper Rome westward and northwestward (Plate 6). Since the Rome rests on the basement in central Tennessee and probably in the Valley and Ridge Province (Plate 6), it is assumed that the entire sedimentary sequence was deposited by northwestward transgressive Lower and Middle Cambrian seas.

XI. AGE OF THE ROME

Rodgers (1953) considered the Rome to be Lower Cambrian in age throughout the Valley and Ridge Province after renaming the upper Rome shale the Pumpkin Valley Shale. This separation of the shale unit from the Rome is based upon the presence in the Pumpkin Valley of alokistocarid trilobites which are characteristic of the Middle Cambrian. This decision to consider all the Rome Early Cambrian in age might not be correct, because Middle Cambrian fossils in the Lee Valley section - on which Rodgers and Kent (1948) based their decision - appear 75 m (247 feet) above the Rome. This still leaves the age of a considerable part of the upper Rome and the lower Pumpkin Valley Shale disputable. Since the Rome represents a transgressive unit, it becomes younger in age northwestward. Thus the Rome's time span is not limited to the Lower Cambrian (see McLaughlin, 1973). According to Amoco geologists (Tennessee Division of Geology, 1974) the contact between the Rome and the Maynardville in Driver No. 1 well (Plate 6) is marked by a fault. This means that the upper Cambrian Nolichucky Shale is missing, and leaves in doubt the age of the Rome in central Tennessee. However, Harris (1964) reports that the Conasauga Shale pinches out westward in the subsurface of central Kentucky. He shows that the Conasauga is Middle Cambrian in the Appalachain Valley and Late Cambrian in the subsurface. Thus the Rome Formation in the subsurface in central Tennessee is probably of Middle Cambrian age.

XII. ROME - SHADY RELATIONSHIP

The interpreted relationship between the Rome and the underlying Shady Dolomite is based on the correlation of three sections in the same strike belt in northeast Tennessee. King et al. (1944) reported the presence of 22 to 30 m (75 to 100 feet) of transition beds from dolomites in the Shady to shale in the Rome. These beds are composed of silty and shaly dolomite and dolomitic shale, with a bed of massive blue - gray dolomite near the middle (Plate 6). Red shale is absent in the transition interval, but occurs in units at the top of the Rome. Below the Rome, the Shady Dolomite consists largely of blue-gray and white dolomite, but includes a small amount of limestone and a few thin beds of shale. Oolites near the top of the formation in the Damascus section, southwest Virginia, indicate that the Shady Dolomite was deposited in a very shallow marine environment. From the general facies relationship between the Rome and the overlying Conasauga Group, it is clear that the contact between the two is neither sharp nor horizontal. Similarly this relationship probably applies to the Shady and the Rome. If more continuous sections of the Shady and the Rome were available across strike, dolomites of the lower Rome would probably be found to merge eastward into the Shady Dolomite, similar to the merging of the Rutledge and Maryville limestones into the Honaker Dolomite (Figure 76). The transition beds at the bottom of the Rome suggest that there might be such a relationship. Clastics of the Rome were deposited west of the eastern edge of the present Appalachian Valley, while carbonates of the Shady were deposited eastward. This relationship is partly similar to that within the clastic and carbonate units within the Conasauga Group, and applies to the Rome and the Shady only southeast of the Valley and Ridge Province. Judging from the general facies relationships, and the paleogeographic history of the southern Appalachians, the upper Shady is probably an eastward and southeastward facies equivalent of the lower Rome.

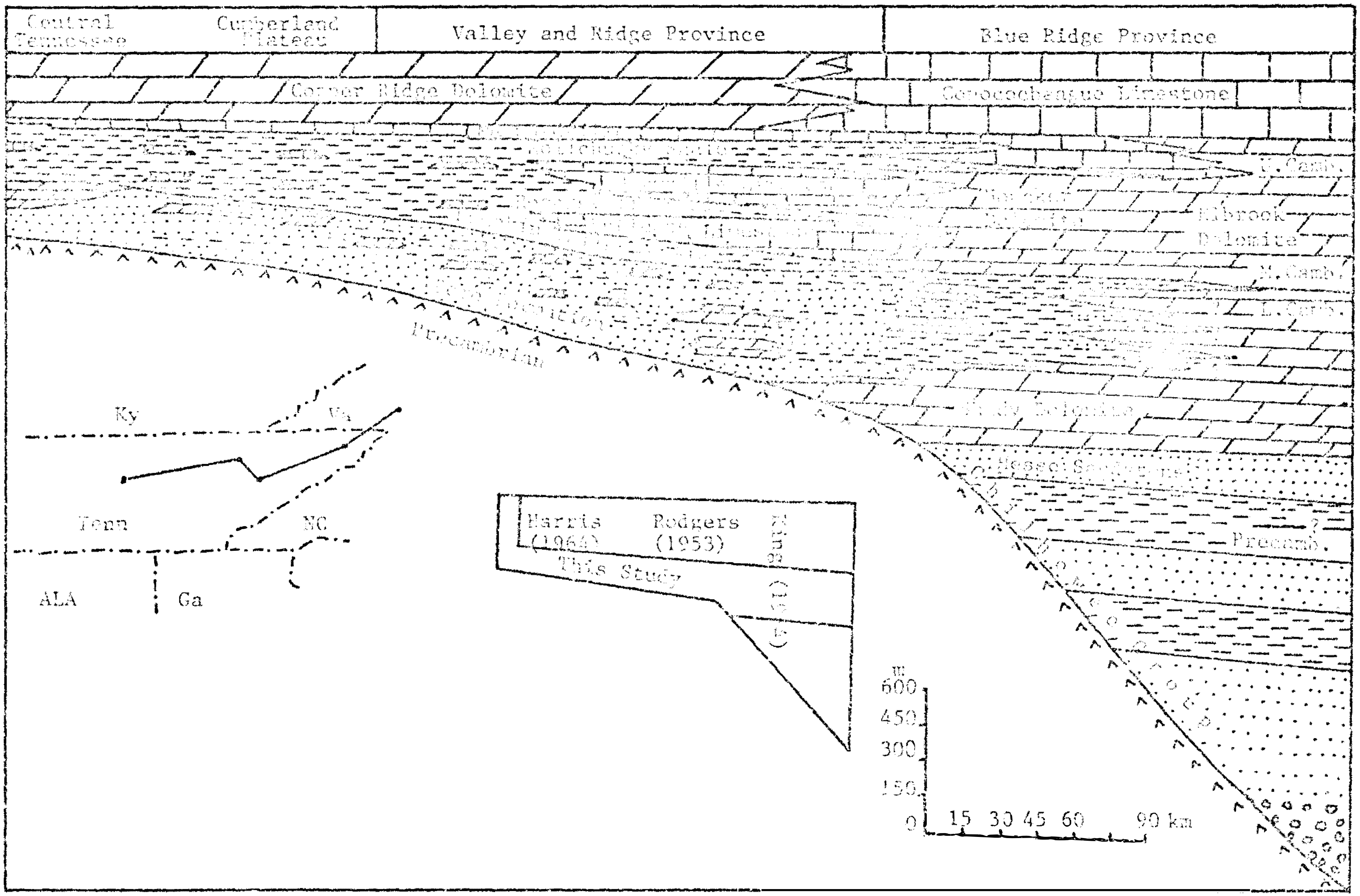

Figure 76. Palinspastic facies relationships of the Cambrian and Precambrian rocks in Tenn. and SW Va..

CHAPTER VIII

PALEOGEOGRAPHY

I. SOURCE OF THE ROME SEDIMENTS

It has been indicated in many Appalachian studies of the Lower Cambrian, Harvey and Maher (1948), Rodgers (1953), Woodward (1949, 1961), Freeman (1953), Colton (1970), that the source of sediments was generally from the west. Pettijohn (1970) showed that during Cambrian time sediment transport was eastward and southeastward into the Appalachian geosyncline. In this study, sand-shale ratios, clastic ratios, cross-bedding and ripple marks were used to determine the source of the Rome Formation in the study area.

Although measurements of symmetrical ripple marks are limited (see Table 9), they indicate a general east - west current with a mean direction of 103° and a shore line which runs in a north - south direction. Large scale cross-bedding is scarce in the Rome Formation; consequently, only eight measurements were available for measurement and those were from sandstone and oolite beds (Table 9). A mean direction of 165° from cross-bedding readings suggests a general paleocurrent direction from the northwest.

Sand-shale ratios computed for the Rome sections in east Tennessee Table 10 and Figure 77), do not show meaningful trends, because the exposed uppermost parts are mostly sandstone. Secondly, the rapid intertonguing of sandstone, siltstone, shale and carbonates in very shallow environments does not lend itself to the determination of distinct trends. Rome clastics from very coarse sandstone to shale were deposited in

Table 9. Cross-bedding and Ripple marks current directions in the study area.

Location	Cross-bedding Direction	Lithology	Location	Ripple Marks Current Direction
Pine Ridge, I-75	140°	Sand	Diggs Gap	85°
	150°	Oolite	Nelson Branch	97°
Oak Ridge	165°	Oolite		125°
	250°	Sand	Pumphouse Road	107°
Young Creek	125°	Oolite		153°
	130°	Sand	Crippen Gap	30°
Sharp Gap	140°	Sand		35°
Shooks Gap	210°	Oolite		65°
				155°
			Sharp Ridge	65°
				110°
				85°
				110°
				160°

Table 9. (Continued)

Location	Cross-bedding Direction	Lithology	Location	Ripple Marks Current Direction
			Porterfield Gap	85°
				95°
				98°
				100°
				105°
				115°
				120°
				125°
				130°
				140°
Mean Direction	165°			103°
Standard deviation ±15.5				

Table 10. Sand-shale and clastic ratios of the Rome Formation in East Tennessee and southwest Virginia.

Section	Sand Shale Ratio	Clastic Ratio	Dominant Lithology	Author
Pine Ridge, I-75	3.0	8.0	Sandstone-Shale	This work
Clinton	1.0		Sandstone-Shale	This work
Oak Ridge	2.0	94.0	Sandstone-Shale	This work
Young Creek	4.0	16.0	Sandstone-Shale	This work
Diggs Gap	4.0	16.0	Sandstone-Shale	This work
Nelson Branch	6.5	16.0	Sandstone-Shale	This work
Pumphouse Road	5.0	29.0	Sandstone-Shale	This work
Dug Ridge	14.0	5.0	Sandstone-Carbonate	This work
Crippen Gap	32.0	3.2	Sandstone-Carbonate	This work
First Creek	2.0	3.0	Sandstone-Carbonate	This work
Sharp Gap	5.2	4.5	Sandstone-Carbonate	This work
Porterfield Gap	4.0	1.5	Sandstone-Carbonate	This work
Shooks Gap	6.5	58.0	Siltstone-Shale	This work
Beaver Ridge Hines Valley	3/8	8.0	Shale-Sand	Spigai, 63 Locality 1
Log Mountain Dutch Valley	3/4	8.0	Shale-Sand	Spigai, 63 Locality 2
Dug Ridge Poplar Springs	1/4	3.0	Shale-Lime	Spigai, 63 Locality 3
Section 25 NE Tennessee	1/8	5.0	Shale-Carbonate	King, 1960
Section 29 SW Virginia	1/8	3.0	Shale-Carbonate	King, 1960
Lee Valley, Pine Ridge	1/5	3.0	Shale-Carbonate	Rodgers and Kent, 1948
Watts Bar Dam	10		Sandstone-Shale	Fox, 1943

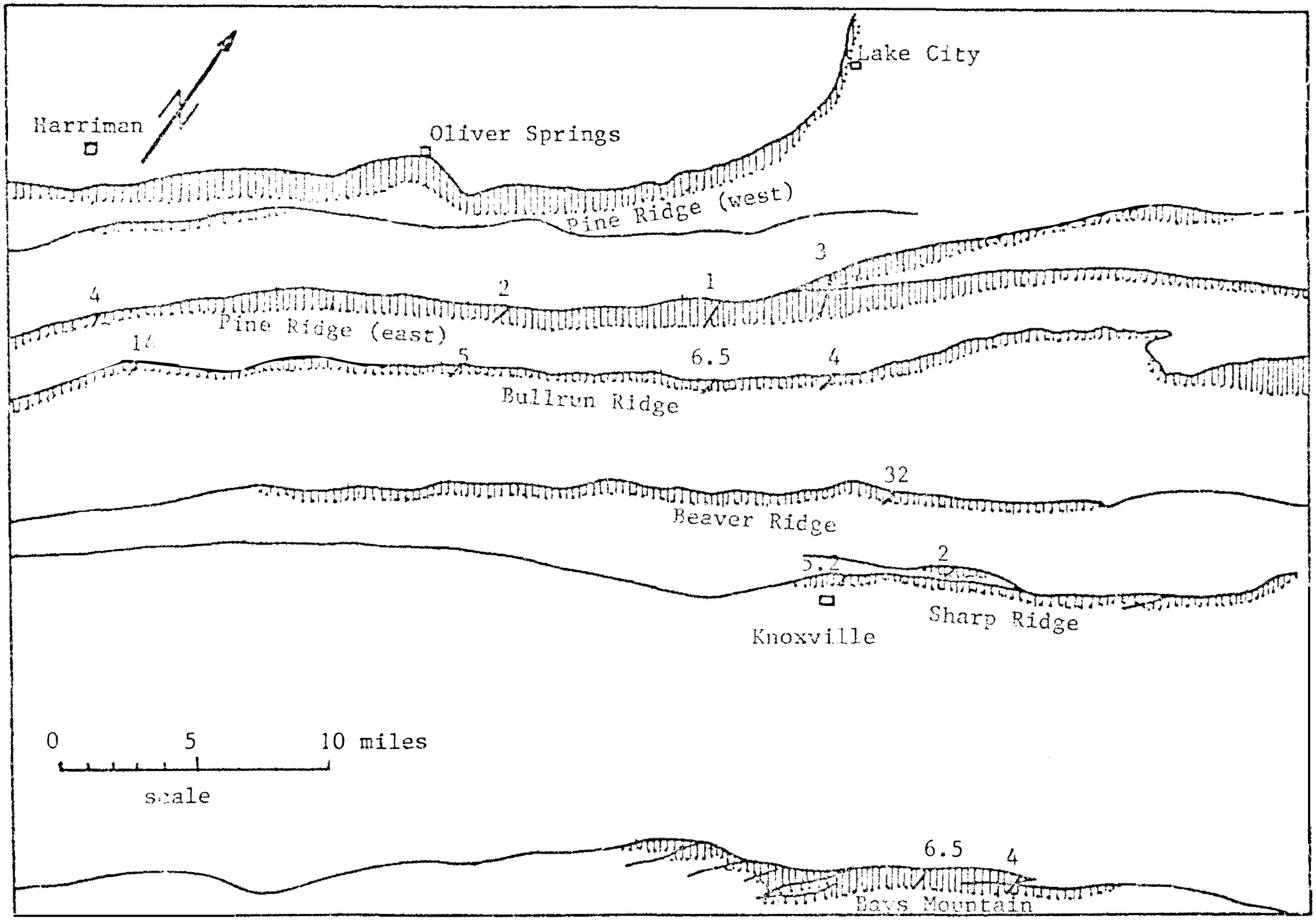

Figure 77. Sand-shale ratio in the Rome Formation. Refer to table 10 for localities.

supratidal to subtidal transitional environments which mask any clastic trends. The formation in the study area represents a transition between the predominantly shaly Rome in northeast Tennessee and the predominantly sandy Rome to the west.

Clastic ratios show a clearer trend with a general increase in carbonates towards the east (Figure 78). The clastic ratio in the Shooks Gap section is not representative of the Bays Mountain belt, because most of the section is covered or missing. Carbonates of the Rome in the study area were deposited in supratidal and intertidal environments and so represent local lenses. But the fact that thrust faults at Sharp Gap, Crippen Gap and First Creek cut through dolomites indicates that probably more carbonate units are faulted out. Thus, clastic ratios in the Rome are biased.

Woodward (1949) claimed that there are no Middle or Lower Cambrian sediments in the vicinity of the Cincinnati Arch, nor anywhere west of it. He believed that those series are probably very thin underneath the eastern Ohio Valley, while to the east of the Ohio the sediments thicken rapidly in the outcrops of the Appalachian Valley. Woodward (1961) noticed a remarkably steep western boundary of Lower Cambrian rocks in western West Virginia. That limit is so abrupt that it suggests a steep continental declevity or a major fault scarp which descends from a Precambrian continental platform to a trough flanking the southeast face of that declevity. In this basin Lower Cambrian rocks and in particular the Rome Formation accumulated tremendous thicknesses (Figure 79). He indicated that the red color of the Rome suggests deltaic or fan-like deposition; he showed that the thickness of the Rome west of the scarp is between 21 and 67 m

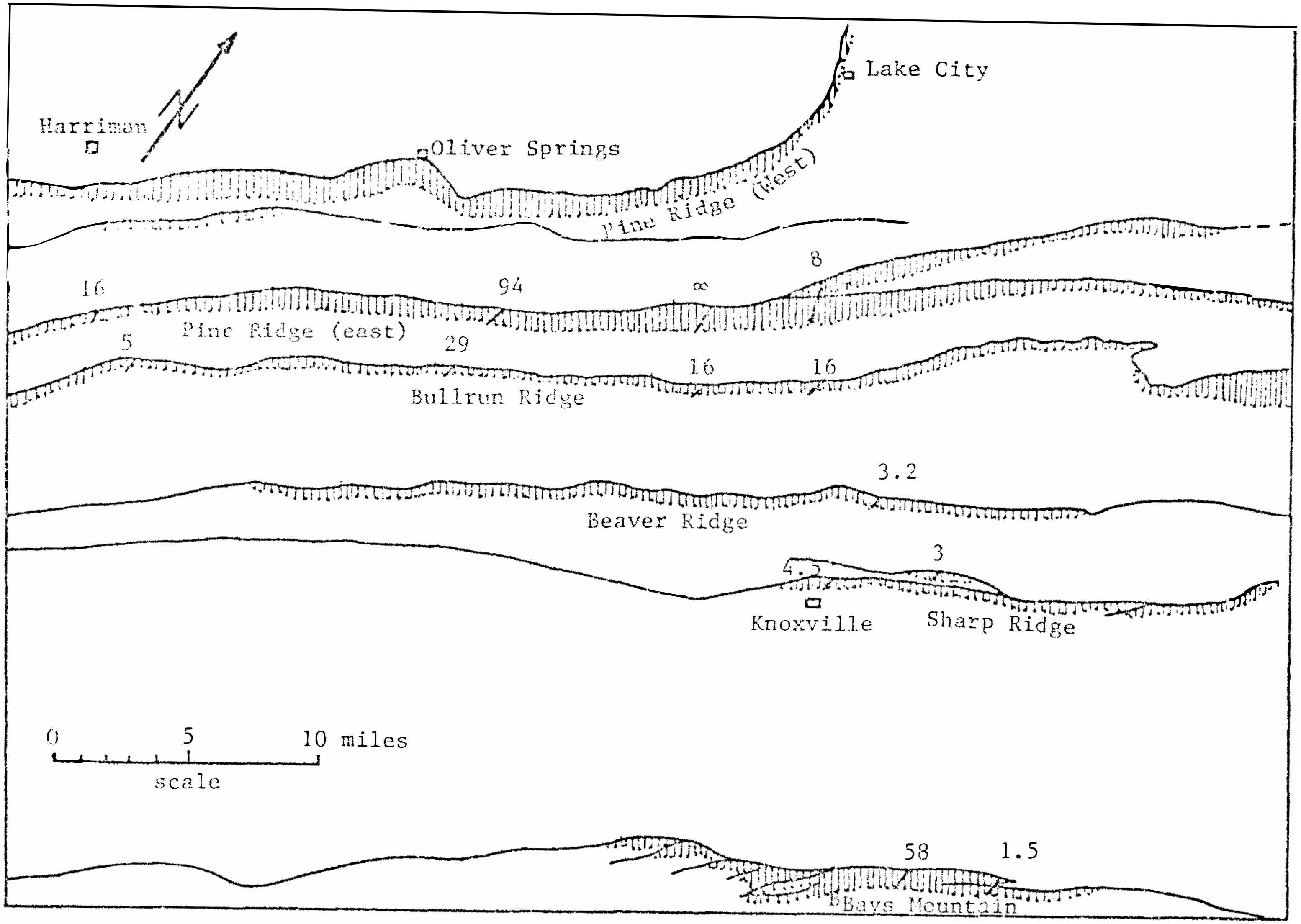

Figure 78. Clastic ratio in the Rome Formation. Refer to table 10 for localities.

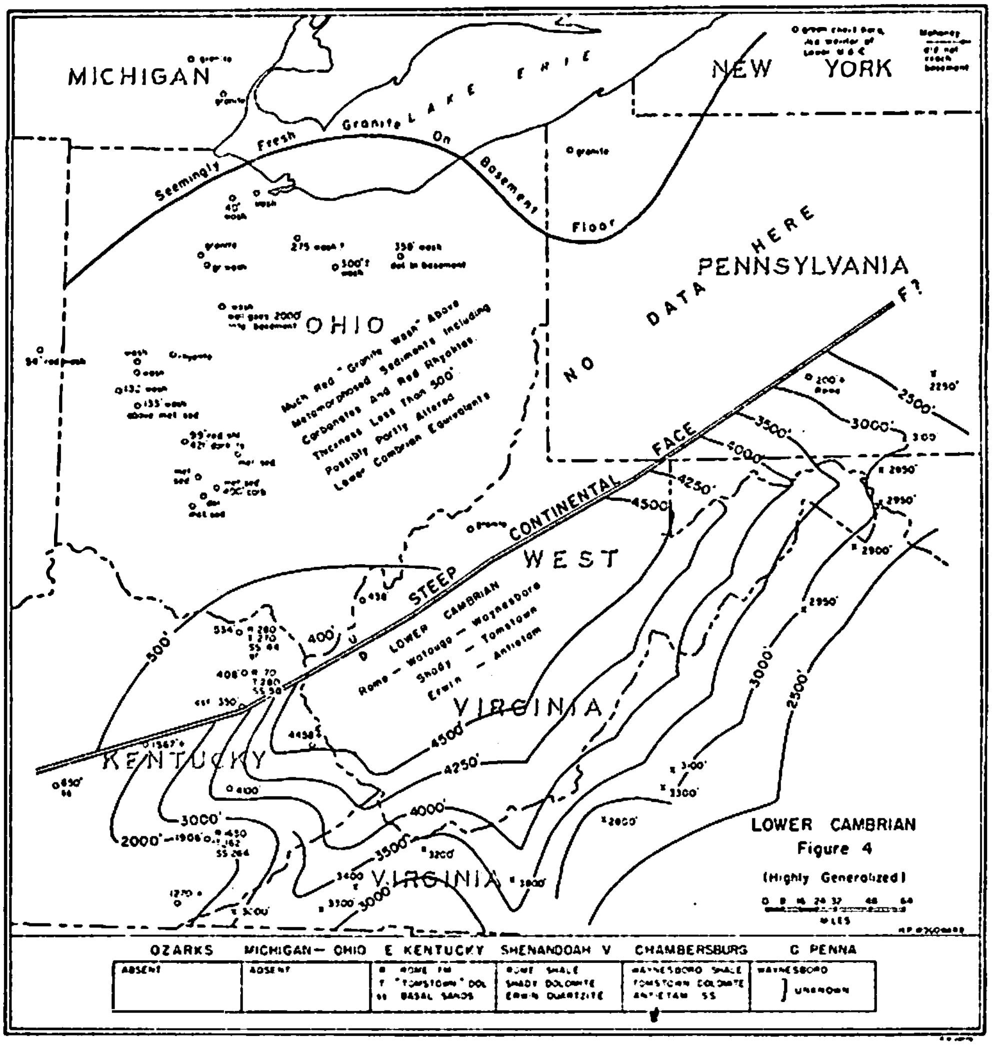

Figure 79. Thickness-distribution map for Lower Cambrian (Woodward 1961).

(70 and 220 feet) while east of the scarp it is more than 600 m (2000 feet) thick (Figure 80), so it is increasingly evident that the Rome was deposited from the northwest.

Freeman (1953) also supports a western source for the Rome sediments. He believes that the eastern edge of the Cambrian continent is roughly within the Blue Ridge Province; from Early Cambrian through Knox time, the sea encroached gradually, depositing on the edge great lenslike masses which thin towards the source landward and thin away from the source seaward. Freeman concluded that the late Lower Cambrian deposits in southern Virginia, east Tennessee and Alabama were Rome sands, silts and shales which represent a large accumulation of deltaic materials and that most of the craton westward was land during all that time (Figure 81).

Wheeler (1960) indicated that there were two sources for the early Palezoic detrital sediments of the eastern United States, the central craton from latest Precambrian to latest Cambrian time, and from late "Beekmantownian" Early Ordovician through "Edenian" time in the Middle Ordovician. The second is the Taconian Borderland in the east from "Maysvillian" time in the late Ordovician into Silurian. Colton (1970) confirms the western source of clastic sediments during Cambrian and Early Ordovician times. He pointed out that in much of the Appalachian basin, the Lower Cambrian clastic sequence delineate a blanket of quartzose and arkosic detritus laid down in the shallow waters of a northwestward transgressing Cambrian Sea. According to him, the sequence is a wedge shaped mass which is thickest along the eastern margin of the basin, where the rocks are mostly Early Cambrian in age, and thinnest along the west and north margins where its rocks are mostly Late Cambrian in age. Colton

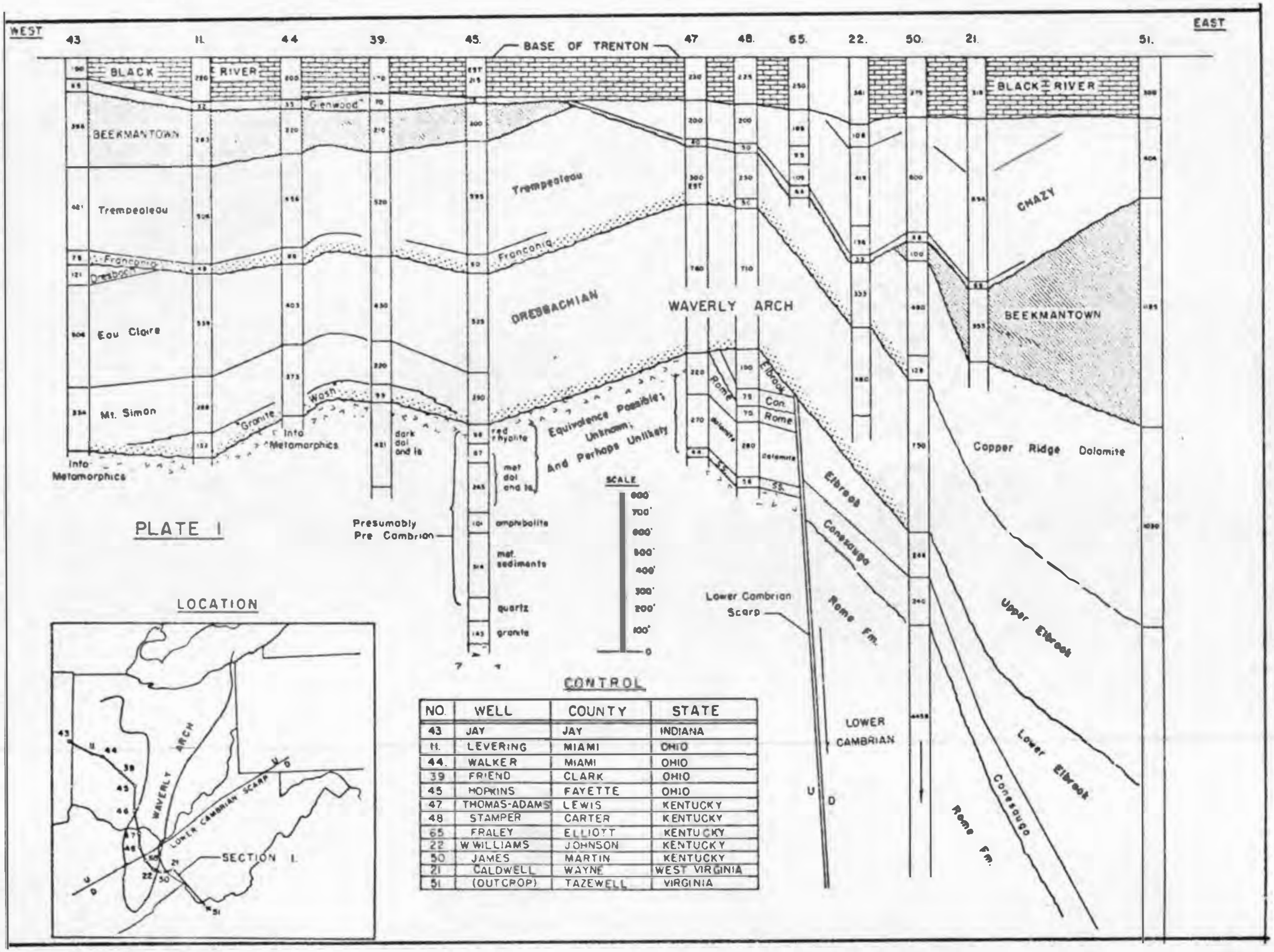

Figure 80. Geologic cross-section across the Appalachians from Indiana to Virginia (Woodward 1961).

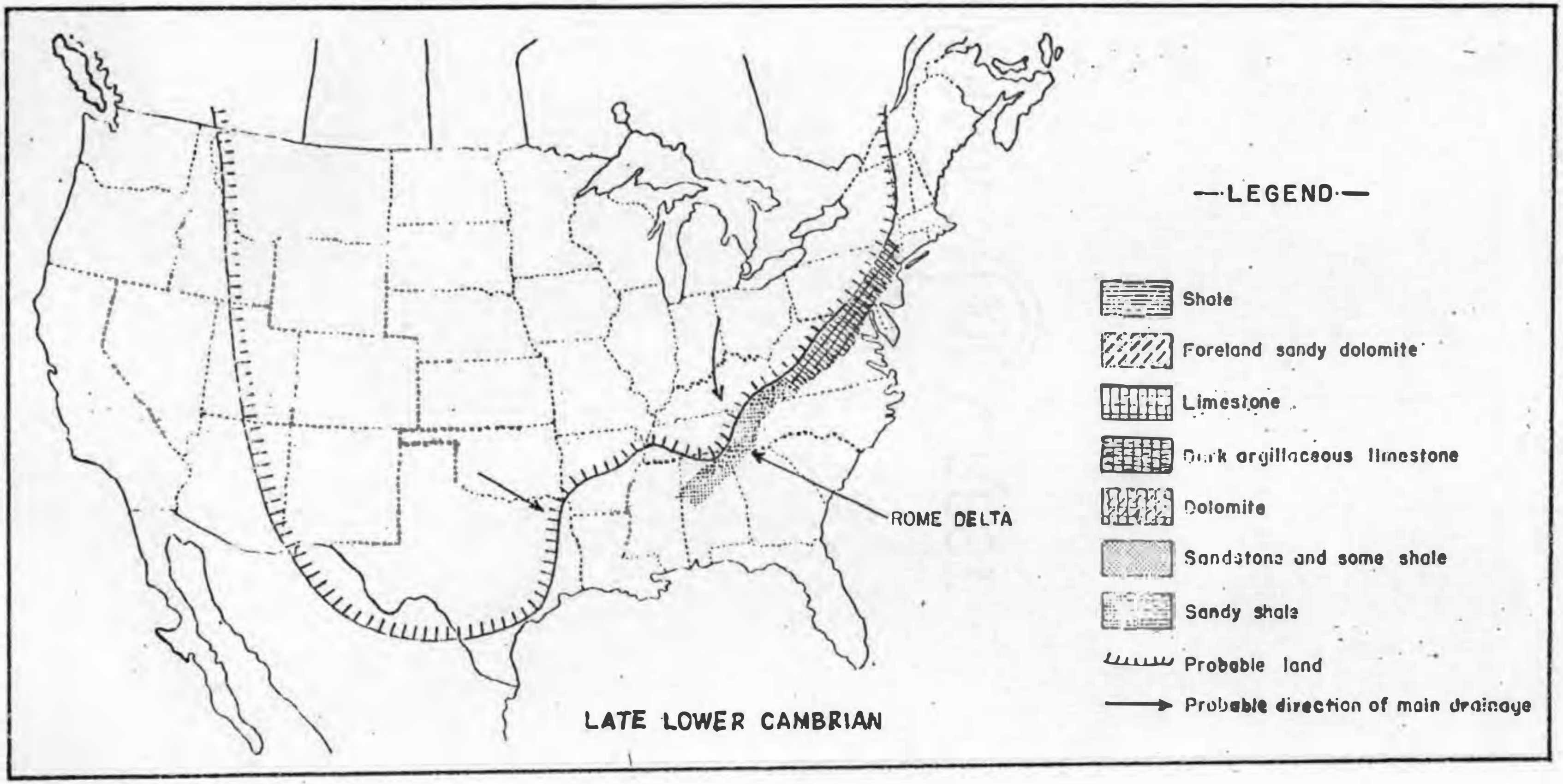

Figure 81. Paleogeographic reconstruction during late Lower Cambrian. (After Freeman, 1953).

reported that the greatest thickness of Lower Cambrian strata, approximately 3050 m (10,000 feet) in southwest Virginia, represent a sequence which thins rapidly from the east edge of the basin to the northwest (Figure 82). So paleocurrent, lithologic and isopach map studies of Early Cambrian sediments indicate a general western source and a southwestward paleocurrent direction in particular.

II. PALEOTOPOGRAPHY

When the Rome sea advanced westward over the craton, it advanced over a gently sloping and undulating topography. Computation of gradients from deep basement wells in central Tennessee (Figure 83A) range from 0.2 m/km to 10 m/km. East to west average gradient between wells 13 to 24 is 3.7 m/km and between 22 to 27 it is 2.6 m/km (Figure 83B). The gradient between wells 16 and 27 is 10 m/km while between 1 and 17 it is 0.2 m/km. The average gradient between 21 and 13 is 5.5 m/km. Thus there is more variation in gradient between wells 13 to 21 (Figure 83C); this might be expected, because there must have been valleys and rivers which drained the craton eastward. The undulating surface of the craton was probably broken by scattered monadnocks and large hills, well number 13 was drilled on such a topographic high. The craton during Early Cambrian in Tennessee and adjacent areas was a landmass that supplied sediment to the Appalachian geosyncline. The persistence of the Rome Formation and its red beds from Pennsylvania to Alabama, indicates that the tidal flat sediment body is elongated parallel to the shoreline over hundreds of kilometers and was probably intersected by tidal channels and estuaries (Figure 84). A modern analogue to such an environment is the tidal flats along the

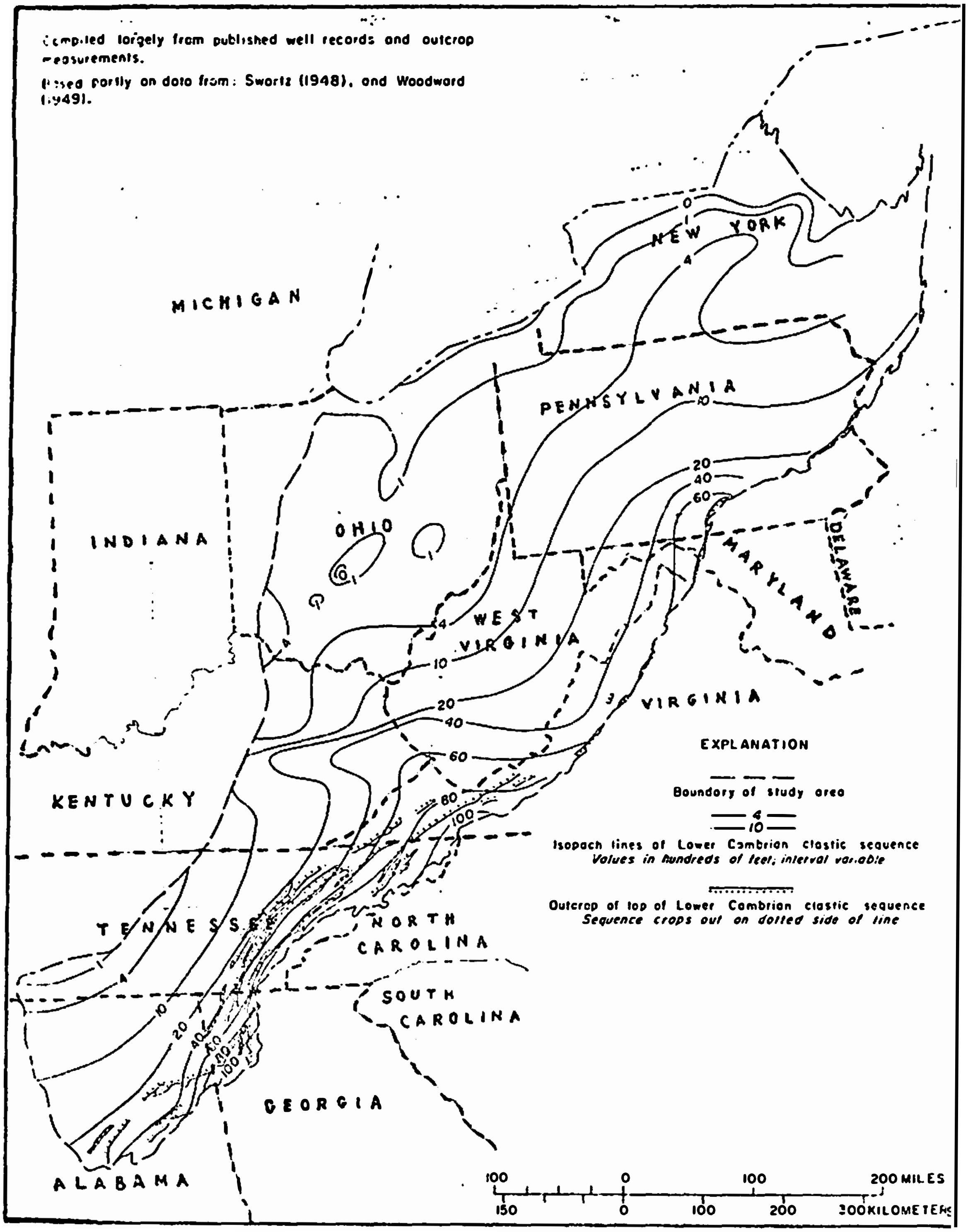

Figure 82. Isopach map of Lower Cambrian clastic sequence. (After Colton, 1970).

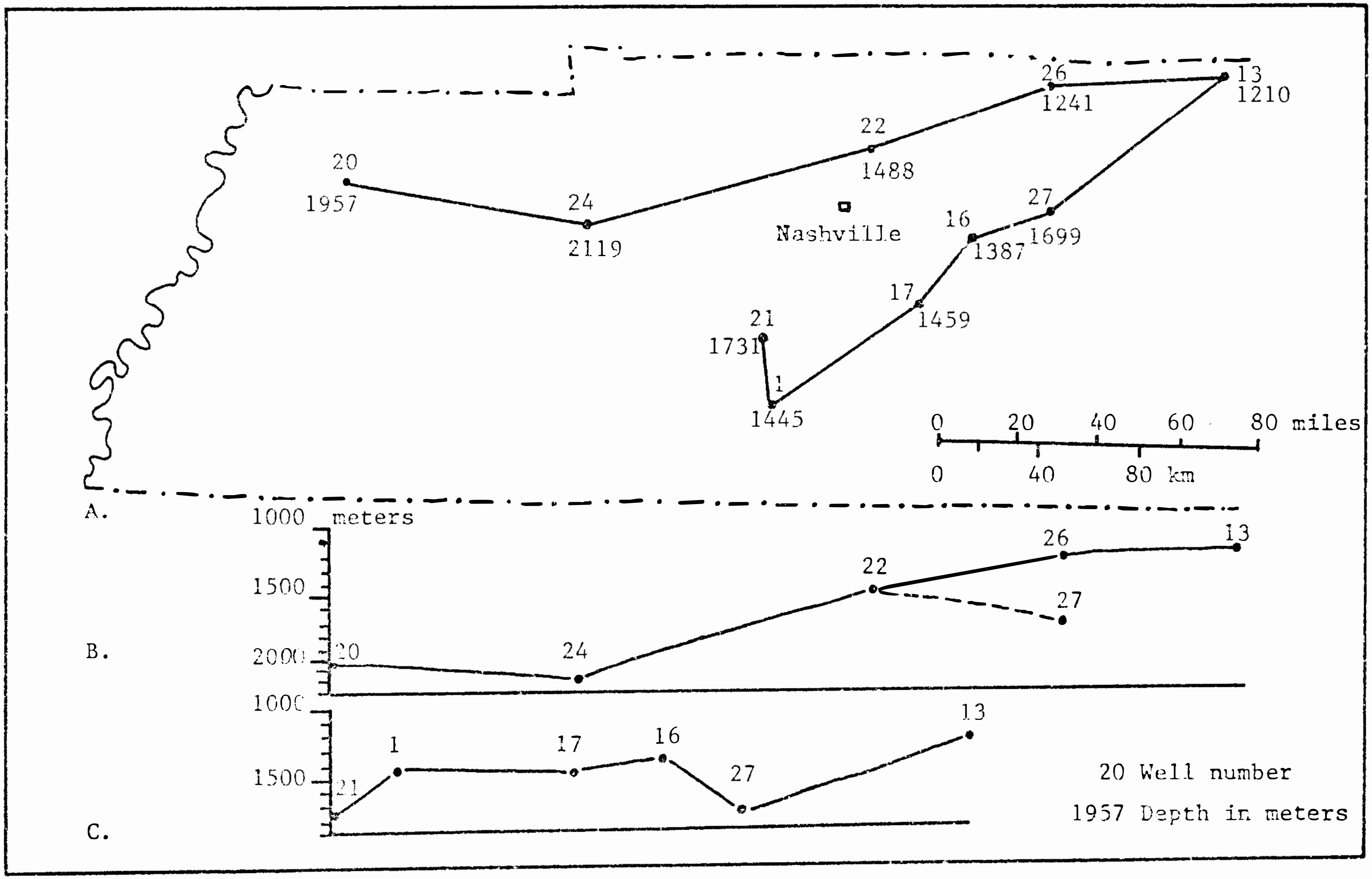

Figure 83. A. Wells penetrating basement adjusted to sea level; B. and C. profiles of the basement. (Source of data, Tennessee Division of Geology, 1974).

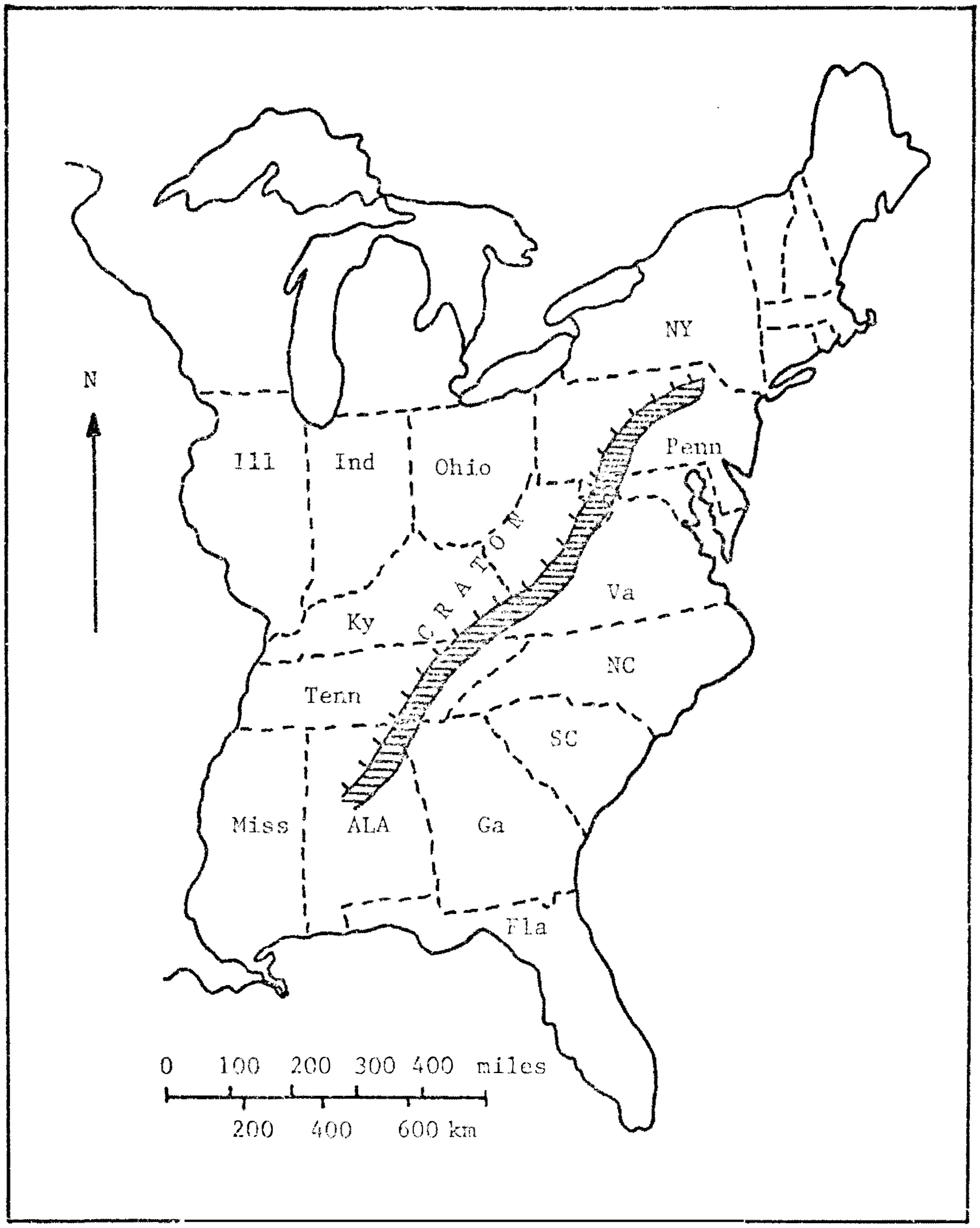

Figure 84. Tidal flats of the Rome in the late Early Cambrian.

coasts of the Netherlands, Germany and Denmark; these flats are 7 to 10 km wide and extend for a distance of 450 km along the shoreline. The gradient across these flats is less than 0.4^{0} (Reineck and Singh, 1973). The maximum gradient computed from the deep basement wells is 10 m/km (0.5°). Although the control points are few in number and relatively widespread, the fact that tidal flats develop on very gently sloping shorelines, support a relatively gently sloping undulating topography over most of the craton in Tennessee.

III. CLIMATE

Red beds in the Rome Formation are associated with sandstones and shales in which iron oxide staining is responsible for the red color. Since red beds are mainly non-marine, they reflect the climatic conditions under which they were formed. It has been indicated by Walker (1967), Van Houten (1968), Dorsey (1926) and Sakamoto (1950) that hematite is an important paleoclimatic indicator unless subjected to strongly reducing conditions and loss of its red color. According to Schmalz (1968) two conditions appear to be necessary for hematite formation: (1) A wet and preferably warm climate in which iron may be released from parent minerals by chemical weathering. (2) A dry climate in which the primary weathered products may be dehydrated. These two requirements may be satisfied in a single environment subject to marked seasonal fluctuations in available moisture.

According to Sakamoto (1950), James (1966), Alexander (1955), Govett (1966), and Douglas, et al. (1972), iron contained in sediments is derived from normal weathering of iron-rich igneous rocks or laterites. Information from deep basement wells in Kentucky (Harris, 1964) and

Tennessee (Tennessee Division of Geology, 1974) indicate that the basement is covered with igneous rocks (Section 1, Plate 6). These rocks were deeply weathered and oxidized on the craton. The weathered products were carried by streams and rivers and deposited on the tidal flats of the Rome, where the already oxidized sediments retained their red color. According to Sakamoto (1950) the deep weathering of igneous rocks and laterization - processes which release iron oxide - are characteristic of tropical zones.

Besides the red beds, the abundance of desiccation features like mud cracks and halite casts in the Rome Formation, indicate a warm climate in which evaporation exceeds precipitation. Such features have been observed in the Colorado tidal flats which have a tropical climate (Thompson, 1968).

Oolites which are found in the Rome Formation (Plates 1, 4, 5) represent another indicator of a warm climate. Besides oolites, algal laminae in dolomites and limestones of the Rome are preserved on tidal flats in warm climates. According to Lowenstam and Epstein (1957), oolites form in waters having temperatures between 24° and 25.7° C, while temperatures of growth for blue green algae range from 22.8° to 39.8° C. The above criteria indicate a tropical climate with pronounced dry and humid seasons during Rome time.

IV. THICKNESS OF THE ROME FORMATION

Estimates of the total thickness of the Rome Formation vary from 300 m (1000 feet) in the western part of the Valley and Ridge Province near Oliver Springs, Tennessee (Swingle, 1960c) to more than 540 m (1800 feet) in the eastern part in the vicinity of Damascus, southwest

Virginia (King *et al.*, 1944). Nowhere in the area of outcrops is there a complete section of the Rome Formation except at Valley Forge in northeast Tennessee (Plate 6). The thickest exposure in the study area is the 334 m (1102 feet) thick Porterfield Gap section, and the thinnest is the 50 m (165 feet) thick Nelson Branch section. Because the Rome is a wedge shaped formation which increases in thickness eastward (Plate 6), the thickness of the Rome differs across strike from one belt to another. Information from basement wells in Kentucky (Harris, 1964) and Tennessee (Tennessee Division of Geology, 1974) indicates that the Rome overlies the Precambrian basement. If the Rome Formation at Bays Mountain and westward is in contact with the basement, a minimum average gradient of 2 m/km for the basement would give the following minimum thicknesses of the Rome in the different belts:

Pine Ridge (East)	320 m	1056 ft.
Bullrun Ridge	340 m	1122 ft.
Beaver Ridge	360 m	1188 ft.
Sharp Ridge	400 m	1320 ft.
Bays Mountain	450 m	1485 ft.

An isopach map of the Rome would then look like Figure 85 in which the Rome Formation pinches out in the vicinity of Nashville.

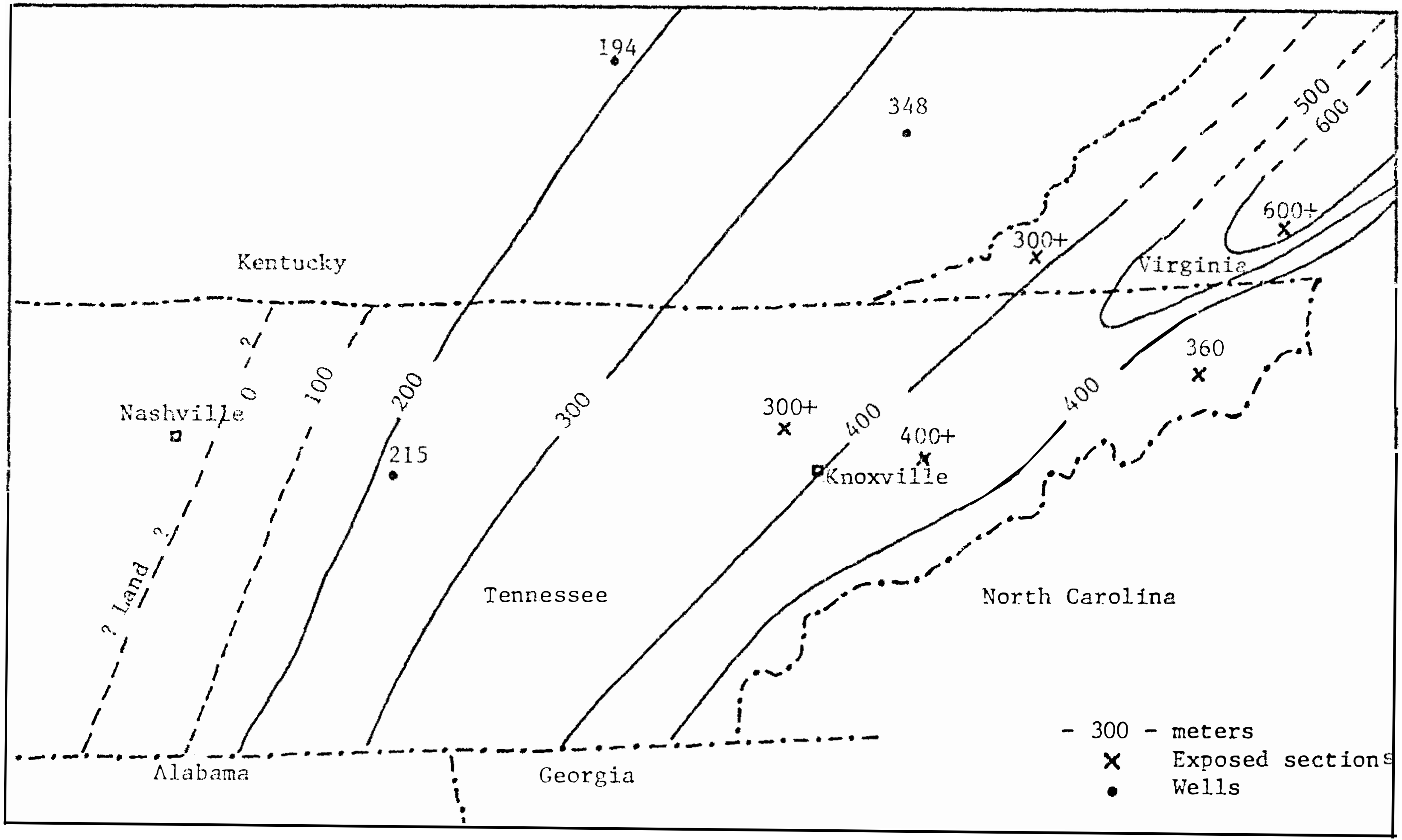

Figure 85. Isopach map of the Rome Formation in East Tennessee.

CHAPTER IX

DEPOSITIONAL HISTORY

Geologic studies in the Appalachians by Woodward (1949, 1961), Freeman (1953), Rodgers (1956), Colton (1970) and Palmer (1970) indicate the existence of the Appalachian geosyncline as early as the Late Precambrian. This deep trough was probably located in the position of the present Piedmont and extended from central Alabama to Nova Scotia in eastern Canada (Figure 86). Pettijohn (1970) envisaged a geosynclinal basin flanked by a great carbonate platform on the west. During Early Cambrian the Chilhowee Group, consisting primarily of conglomaretes, sandstones and shales, filled the deep trough. These sediments spread northwestward out of the trough onto the basement southeast of the present Valley and Ridge Province.

The fossil-bearing Lower Cambrian Shady Dolomite, besides representing a change in lithology from the Hesse Sandstone below, indicates shallow marine conditions. The Shady is absent in central Tennessee and Kentucky where wells have been drilled to basement (Plate 6). The carbonate deposits of the Shady were deposited in a warm, shallow sea in the geosynclinal trough, and extended without interruption from Pennsylvania to Alabama. It probably did not extend northwestward all the way across the area of the present Valley and Ridge Province.

The renewal of detrital deposition above the Shady Dolomite during the remainder of Early Cambrian time is marked by the deposition of the Rome Formation. The Formation is made up of red, purple, green and brown sandstone, siltstone and shale and local beds of limestone and dolomite.

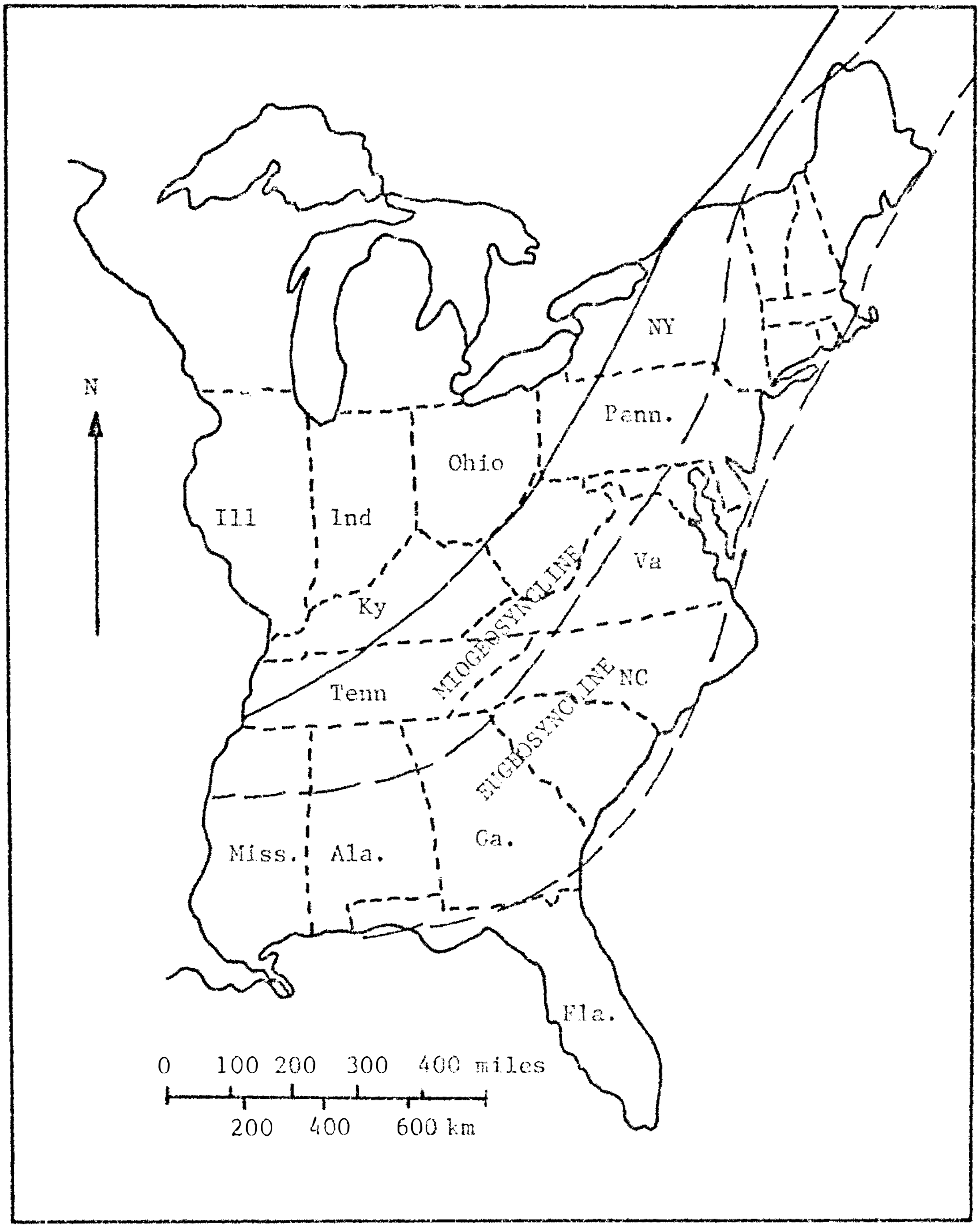

Figure 86. The Appalachian geosyncline.

It is dominantly sandstone in the northwest part of the Appalachian Valley, while to the southeast in Bays Mountain and in northeast Tennessee, the percentage of carbonates increases significantly (Plate 6). These sediments were deposited in a tidal flat environment, as the Rome sea advanced northwestward over a gently sloping basement across the present Valley and Ridge Province and into central Tennessee. The sea remained very shallow throughout Rome deposition. The Rome Formation thickens southeastward; it is 360 m (1200 feet) thick in northeast Tennessee (Plate 6) and is less than 215 m (710 feet) thick in central Tennessee and probably pinches out in the vicinity of Nashville. The appearance of the Rome at the base of the section in thrust sheet after thrust sheet in the Appalachian Valley in Tennessee suggests that the Rome shale served as a slide plane for thrust faults; because the Rome is the first formation above the basement rocks in the valley. Woodward (1961) indicated the presence in West Virginia along a northeast-southwest line probably extending for more than 800 km, that there is a very steep declevity or escarpment descending from a Precambrian continental platform to a trough flanking the southeast face of that declevity. In this basin Lower Cambrian rocks and in particular the Rome accumulated to tremendous thickness. The presence of this declevity suggests the presence of regional down faulting to the southeast of this escarpment in West Virginia. According to Dietrich Roeder (personal communication, 1975) sea floor spreading in the Appalachians started in Late Precambrian. Normal faulting as a result of spreading continued into the Early and Middle Cambrian when the Rome Formation and the Conasauga Group were deposited. The faulting was contemporaneous with the deposition of the

Rome. It is not known if this faulting affected the Rome in Tennessee, since no deep wells penetrated the basement in the Appalachian Valley in Tennessee. Deep wells in central Tennessee do not show that there is a declevity similar to that in West Virginia.

The source of the Lower and Middle Cambrian sediments was to the northwest. This source provided the conglomerates, sandstones and shales of the Chilhowee Group when the craton was high and rugged. By the time the Shady Dolomite and the Rome were deposited the craton was peneplained. Only very fine sandstones, siltstone, shale and carbonates were deposited in a very shallow sea. Rocks of the Conasauga Group, which is made up of alternating tongues of shale and limestone, were deposited in such a shallow sea. Shales of the Pumpkin Valley, Rogersville and Nolichucky thicken northwestward, while limestones of the Rutledge, Maryville and Maynardville pinch out and become lenses in the same direction. Southeastward the shales pinch out, while the limestones thicken and merge into the Honaker Dolomite. The whole Conasauga Group wedges out northwestward (Figure 76, page 159).

The last important influx of mud into the Appalachian trough from the northwest occurred in Nolichucky time. Mud spread over the area of the Valley and Ridge Province and eastward during Late Cambrian but was then followed by the deposition of the Maynardville Limestone and the overlying Copper Ridge Dolomite and its equivalent the Conococheague Limestone in the southeast. At this time the sea spread westward out of the Appalachian trough over most of the central United States. The sea was shallow, but the slightly thinner deposits on the northwest may have been laid down in somewhat shallower water than those on the southeast.

CHAPTER X

SUMMARY AND CONCLUSIONS

The Rome Formation is composed predominantly of very fine-grained sandstone and shale with occasional beds of limestone and dolomite. The proportion of these lithologies varies greatly along and across the strike of Rome outcrops in east Tennessee, but there is a general increase in the proportion of shale and carbonates southeastward, while sandstones and siltstones increase in proportion northwestward in the Appalachian Valley. The Rome Formation is a wedge-shaped unit that thickens southeastward and wedges out in central Tennessee indicating a generally western source for the Rome sediments.

The appearance of the Rome at the base of the section in thrust sheets suggest that the Rome shale served as a slide plane for thrust faults. The Rome being the first formation above the basement rocks in the Appalachian Valley.

Sedimentary structures indicating a tidal flat environment are abundant in the Rome. These structures are: mud cracks, halite crystal casts, ripple marks, rain prints, tidal balls, cross-bedding, ripple laminae, current lamination, scour and fill, flute and groove casts, load casts, vugs, birdseye and flaser and lenticular bedding.

Trace fossils found in the Rome in order of decreasing abundance are: Planolites, Skolithos, Rusophycus, Cruziana, Scoyenia, fecal pellets, Sinusites, Phycodes, Bergaueria, Diplichnites, Dimorphichnus, and Monomorphichnus. The most important environmental indicators are Scoyenia (Supratidal), Skolithos (beach), and Cruziana (supratidal to subtidal). The Cruziana facies in the Rome Formation does not fit Seilacher's ichnofacies model in which Cruziana is confined to the subtidal zone.

Environments of deposition in the Rome range from supratidal to subtidal. Three important criteria distinguish the supratidal sediments in the Rome from sediments formed elsewhere on the tidal flat. First, the presence of Scoyenia in red beds; second, halite casts and mud cracks; third, laminated dolomites with mud cracks and birdseye.

Tidal flat sediments in the Rome are differentiated into mud flat, mixed flat, and sand flat. Mud flat deposits are represented by red beds, abundant mud cracks, biogenic structures, bioturbation and laminated shale, siltstone and very fine-grained laminated to thin-bedded red sandstone.

The mixed flat deposits are represented by the rapid alternation of laminated sandstone and shale. The position of the mixed flats as a transition zone between the mud flat and sand flat, causes the mixed flat to contain features of both zones--from the mud flat, the red shales and sandstones; from the mixed flat the greenish gray and pale yellowish brown sandstone.

Greenish gray, light brownish gray and grayish orange thin-to thick-bedded sandstone beds in the Rome Formation were probably desposited on sand flats and in the shallow subtidal zone. Current lamination and micro cross-bedding are common in these sandstones which are characterized by the absence of mud. Bioturbation and trace fossils are not common in this environment.

Sediments of the tidal flat gullies in the Rome differ markedly from the underlying and overlying sediments. They are generally coarser and arranged in steeply inclined layers.

The lagoonal environment in the Rome is indicated by the presence of superficial, single nucleate and composite ooids, glauconite, and well rounded, well sorted intraclasts. The oolite shoals, on the other hand, are represented by mature, well sorted "Bahaman type" ooids which are interlaminated with well rounded glauconite pellets. These shoals are limited vertically and horizontally in the Rome Formation.

The Rome Formation shows a general transgressive sequence upwards with prograding (regressive) and retrograding (transgressive) deposits alternating at the top of the sections. Although individual beds in the formation cannot be traced across the strike transgressive and regressive sequences which depend upon environmental interpretation can be correlated successfully.

Within the study area, units of the Rome can be traced easily along strike for long distances. The detailed study of the Rome stratigraphy revealed the presence of marker beds. These beds or sequences could be lithologically correlated for more than 40 km. along Pine Ridge and for shorter distances along the other ridges. Correlation across strike was achieved by the tracing of the oolite zone and the Skolithos zone above it over a palinspastic distance of 105 km. (66 miles). These two zones mark the upper part of the Rome Formation; they are not contemporaneous, but represent similar environments at those levels.

The Pumpkin Valley Shale which is Middle Cambrian in age is by lateral gradation a facies equivalent of the upper Rome northwestward; while the top of the Shady Dolomite is a facies equivalent of the lower part of the Rome. Thus, the Rome is of late Early Cambrian age in the

Appalachian Valley and probably Middle Cambrian in the subsurface in central Tennessee.

When the Rome sea transgressed westward over the craton, it advanced over a gently sloping and undulating topography. The craton during Early Cambrian in Tennessee and adjacent areas was a landmass that supplied sediment to the Appalachian geosyncline. The persistance of the Rome Formation and its red beds from Pennsylvania to Alabama, indicates that the tidal flat sediment body is elongated parallel to the shoreline over tens of kilometers and was probably intersected by tidal channels and estuaries. During that time a tropical to subtropical climate with pronounced dry and humid seasons prevailed.

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APPENDIX

APPENDIX

PINE RIDGE I-75 SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			Pumpkin Valley Shale
153*	1.77	1.77	Quartzitic sandstone, greenish gray, very fine grained, very thin to thin bedded. Very fine glauconitic laminations, light brown shale laminations, ripple marked.
152	1.57	3.34	Sandstone, pale brown, very fine grained, mostly very thin to thin bedded with occasional medium beds. Three very thin shaly sandstone beds, yellowish gray are in the middle. Some medium beds pinch out.
151/1*	0.91	4.25	Sandstone, greenish gray to very pale orange, very fine grained, very thin bedded.
151/2	1.14	5.39	Sandstone, medium gray and sandy shale, dark yellowish orange, very fine to fine grained, very thin to thin bedded. Weathering makes the sandstone look shaly. Some surfaces are rusty red.
150	0.96	6.35	Sandstone, pale yellowish brown, very fine to fine grained, medium bedded, with laminated shaly sandstone between beds. Some beds are pale brown.
149/1*	1.22	7.57	Sandstone, greenish gray, very fine grained, thin bedded. Weathered surfaces are rusty red, beds look shaly.
149/2	0.96	8.53	Quartzitic sandstone, varicolored dark greenish gray to pale yellowish brown, very fine grained, medium bedded. Rusty red surfaces.

Unit	Thickness In Meters	Cumulative Thickness	Description
149/3	0.40	8.93	Shaly siltstone, light greenish gray, medium bedded. Weathered surface is dark yellowish orange.
149/4	0.20	9.13	Quartzitic sandstone, dark greenish gray, very fine grained, medium bedded. Color becomes gradually brownish at the top of the bed.
148/1	1.93	11.06	Alternate quartzitic sandstone and shaly siltstone in which the contacts are gradational, light greenish gray, very fine grained, medium bedded. Weathered surface is dark yellowish orange. Some shaly siltstone beds pinch out, they are bioturbated.
148/2	1.09	12.15	Quartzitic sandstone, greenish gray to light gray, very fine to fine grained, medium bedded. Very fine wavy laminations inside the beds.
148/3	0.81	12.96	Sandstone, pale yellowish brown, fine to medium grained, medium bedded. Internal fine wavy laminations. Fine flaser bedding the two beds. Limonitic weathered surface.
147	0.96	13.92	Dolomite, medium gray, very thin bedded, grades laterally into very thin bedded, very fine grained sandstone which is dark yellowish orange.
			FAULT
146/1*	0.86	14.78	Sandstone, yellowish gray, very fine to medium grained, mostly medium bedded with occasional very thin to thin beds and laminated shaly sandstone. Light greenish gray bedding planes.
146/2	0.73	15.51	Sandstone, pale brown, very fine to medium grained, very thin to thin bedded. Some glauconitic laminations are 1 cm. thick. Fractured and jointed.

Unit	Thickness In Meters	Cumulative Thickness	Description
146/3	0.15	15.66	Alternate very thin bedded sandstone and laminated shale, pale olive, sandstone is very fine to medium grained. 20% Shale.
146/4	0.33	15.99	Sandstone, grayish red, medium grained, very thin to thin bedded with fine internal shale laminae. Fractured and jointed.
146/5*	1.32	17.31	Quartzitic sandstone, light greenish gray to light gray, very fine to fine grained, mostly thin bedded with occasional medium and very thin beds. Some beds are current laminated. Some beds are lens shaped.
146/6	1.30	18.61	Sandstone, grayish red, very fine to fine grained, very thin to thin bedded, with two horizons of laminated shale and sandstone 5 cm. thick each bottom and middle of unit. Flaser bedding in laminated shale and sandstone. Current laminations in some beds. Planolites on lower bedding of some beds.
145/1	0.33	18.94	Alternate laminated sandstone and thinly laminated shale, grayish red, fine grained. Flaser bedding.
145/2	1.00	19.94	Sandstone, pale brown, fine to medium grained, very thin bedded. Current laminated.
145/3	0.78	20.72	Alternate very thin bedded sandstone, fine grained and laminated shale, grayish red. 10% Shale. Current laminated.
145/4	0.91	21.63	Alternate very thin bedded sandstone, very fine to fine grained and laminated shale, grayish red. 40% Shale. Flaser bedding. Current laminations in sandstone beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
144	0.81	22.44	Sandstone, pale brown, very fine to fine grained, very thin to thin bedded. Ripple marked, light greenish gray bedding planes.
143/1	0.50	22.94	Alternate very thin bedded sandstone, very fine to fine grained and laminated shale, grayish red. 10% Shale. Flaser bedding.
143/2	0.38	23.32	Sandstone, grayish red, very fine to fine grained, very thin to thin bedded. Thin beds pinch out.
143/3*	0.81	24.13	Sandstone, grayish red, very fine to fine grained, mostly very thin bedded to laminated with few intervening thin beds at the bottom. Bottom beds are bioturbated. <u>Planolites</u> on lower bedding plane. Current laminations in some beds.
142/1*	0.66	24.79	Sandstone, greenish gray, very fine to fine grained, very thin bedded; weathered surface is dark gray. Some of the beds are shaly. Micro cross bedding in some beds. Bioturbated. <u>Planolites</u> on lower bedding plane.
142/2	0.30	25.09	Sandstone, pale greenish yellow, very fine grained, very thin bedded. Bottom of unit is pale brown sandy shale. Bioturbated, bedding is not clear.
			SMALL FAULT
141/1	0.66	25.75	Sandstone, grayish red, very fine to fine grained, thin bedded. Sandstone beds pinch out.
141/2	0.30	26.05	Sandstone, grayish red, very fine to fine grained, laminated to very thin bedded.
141/3	0.13	26.18	Sandstone, grayish red, very fine to fine grained, thin bed.

Unit	Thickness In Meters	Cumulative Thickness	Description
141/4	0.55	26.73	Sandstone, grayish red, very fine to fine grained, very thin bedded with intervening laminated shale. 5% Shale. Flaser bedding. 5 cm. thick bed is bioturbated at the bottom. Ripple marks. Current laminated.
			SMALL FAULT
140/1*	0.22	26.95	Quartzitic sandstone, greenish gray, fine to medium grained, very thin to thin bedded. Ripple marked. Fine internal laminations in sandstone beds are reddish in color.
140/2	2.79	29.74	Alternate quartzitic sandstone and shaly sandstone, greenish gray, very fine to medium grained, laminated to very thin bedded. Ripple marked. Shaly sandstone beds are flasered. Some beds are current laminated. Planolites on lower bedding planes.
139	0.94	30.68	Alternate laminated shale and very thin bedded sandstone and shaly sandstone, fine to medium grained, greenish gray. Current laminated.
138/1	0.30	30.98	Shale and shaly sandstone, dark greenish gray, very fine to fine grained, laminated. 50% Shale. Flaser bedding.
138/2	0.45	31.43	Laminated shale and shaly sandstone, dusky yellow with a greenish tinge, very fine to fine grained. 50% Shale. Flaser bedding.
138/3	1.17	32.60	Alternate laminated grayish red shale and greenish gray shaly sandstone, fine to medium grained, with very thin bedded, greenish gray glauconitic sandstone at the bottom. 40% Shale. Flaser bedding.

Unit	Thickness In Meters	Cumulative Thickness	Description
138/4	1.12	33.72	Alternate laminated, shale and shaly sandstone, medium yellowish brown to pale brown, fine to medium grained. Flaser bedding. Limonitic weathered surface.
137*	3.45	37.17	Alternate quartzitic sandstone and shaly sandstone, greenish gray to dark greenish gray, fine to medium grained, with pure lenses of coarse grained sandstone in the middle of unit; mostly very thin bedded with occasional laminated and thin beds. Ripple marked. Shaly sandstone is flasered. Planolites on lower bedding plane of some beds.
136/1	0.94	38.11	Sandstone, pale red, very fine to fine grained, mostly thin bedded with occasional very thin beds and one medium bed at the top; light greenish gray upper and lower bedding planes.
136/2*	1.62	39.73	Sandstone, grayish red, very fine to fine grained, very thin bedded with greenish gray laminated shale between beds. Ripple marked; current laminated. <u>Planolites</u> on lower bedding plane of some beds.
136/3	0.63	40.36	Shaly sandstone, grayish red, very fine to fine grained, mostly laminated with some very thin beds and dark greenish gray bedding planes. Shales increases towards the top.
135/1	0.46	40.82	Sandstone, greenish gray, mostly medium grained with occasional coarse and fine grained beds, laminated. 5% Shale.
135/2	0.28	41.10	Shaly sandstone, greenish gray, fine to medium grained mostly thin, with occasional very thin beds. Unit looks bioturbated.

Unit	Thickness In Meters	Cumulative Thickness	Description
135/3	0.38	41.48	Alternate laminated shale and very thin to laminated sandstone, very fine to fine grained, greenish gray to dark greenish gray. 50% Shale. Flaser bedding. Some sandstone beds are lenses. Beds are mostly laminated.
135/4	1.14	42.62	Sandstone and shaly sandstone greenish gray, fine grained with a coarse grained sandstone horizon 15 cm. thick in the middle of unit, mostly very thin bedded with occasional thin beds. Ripple marked. Planolites on lower bedding plane of some beds.
134	1.12	43.74	Sandstone and shaly sandstone, pale brown, fine grained thin to medium bedded. The whole unit is bioturbated and made up of transported burrow casts which are more abundant in some levels. (Similar to OR 70.)
133	0.41	44.15	Quartzitic sandstone, greenish gray, very fine to fine grained, very thin to thin bedded. Coarse grained glauconitic lenses at the top of unit.
132	0.25	44.40	Sandy shale, pale olive, very fine grained, laminated, weathered surface is grayish orange. Slightly bioturbated.
131/1*	0.20	44.60	Alternate laminated shale and very thin to laminated, very fine to fine grained sandstone, grayish red. Flaser bedding. Beds are mostly laminated.
131/2	0.35	44.95	Sandstone, grayish red, very fine to fine grained, very thin bedded with occasional laminated beds. Ripple marked; planolites on lower bedding planes.

Unit	Thickness In Meters	Cumulative Thickness	Description
130	0.50	45.45	Alternate quartzitic sandstone and silty sandstone, pale olive, fine to coarse grained, laminated to very thin bedded. Limonitic blotches on surface.
129/1*	0.18	45.63	Sandstone, white to pale green, coarse to very coarse grained, thin bed. Quartz grains are rounded; slightly glauconitic.
129/2*	0.23	45.86	Sandstone, grayish red, coarse to very coarse grained, medium bed. Quartz grains are rounded.
129/3	0.15	46.01	Sandstone, grayish red, fine to coarse grained, very thin bedded. Current laminated.
129/4	0.91	46.92	Sandstone, grayish red, fine grained with occasional bands of glauconitic very coarse sandstone at the bottom, medium bedded. Current laminated at the top.
128/1	1.27	48.19	Alternate very thin bedded grayish red, fine grained sandstone and laminated dark greenish gray shale. Occasional medium grained sandstone lenses. Laminated shale and sandstone are flasered; current laminated. Micro cross bedding in sandstone lenses. Vertical worm burrows in a 3 cm. thick sandstone bed in the middle.
128/2	0.68	48.87	Sandstone, pale brown, very fine to fine grained, with occasional coarse grained lenses; most beds are laminated with occasional very thin beds and two thin beds at the bottom. Laminated sandstone and shale are flasered. Current laminated; glauconitic sandstone has salt and pepper texture. Vertical worm burrows in some coarse grained sandstone lenses.
127/1*	1.04	49.91	Alternate quartzitic sandstone and shaly sandstone, greenish gray to light gray, very fine to medium grained, very thin to thin bedded; coarse grained sandstone lenses are slightly glauconitic.

Unit	Thickness In Meters	Cumulative Thickness	Description
			There are about 10 horizons of Skolithos 3 to 5 cm. thick each. Shaly sandstone is flasered.
127/2	0.38	50.29	Shaly sandstone, pale grown with a greenish gray tinge, fine to medium grained, medium bedded. Looks flasered.
127/3*	0.15	50.44	Quartzitic sandstone, greenish gray, medium to coarse grained, very thin bedded, with intervening shaly sandstone. Shaly sandstone is flasered. Salt and pepper texture in sandstone due to the presence of glauconite. Sandstone beds thin and thicken. Vertical worm burrows in some beds.
127/4	2.22	52.66	Shaly sandstone, greenish gray, with laminated pale brown shale at the bottom, fine grained with coarse grained sandstone pockets at the top and bottom of unit. Unit looks like one massive bed. Planolites, bioturbated. Flaser bedding in some horizons.
127/5*	0.05	52.71	Sandstone, grayish red, coarse grained, very thin bedded, with occasional intervening laminated shale, unit is hematitic. Bed thins and thickens; quartz grains are rounded.
127/6	0.61	53.32	Alternate, very thin bedded, very fine to medium grained greenish gray sandstone and pale brown laminated shale. Ripple marked; current laminated. Flaser bedding in some horizons.
127/7	3.12	56.44	Sandstone, greenish gray, fine to medium grained, very thin bedded with intervening pale brown laminated shale and shaly sandstone. Glauconitic sandstone has salt and pepper texture. Ripple marked, micro cross-bedding. Shale and shaly sandstone are flasered. One sandstone horizon has vertical worm burrows.

Unit	Thickness In Meters	Cumulative Thickness	Description
127/8	1.37	57.81	Alternate laminated shale and sandstone, very fine to medium grained, pale brown; medium grained glauconitic sandstone abundant at the bottom. Sandstone beds are current laminated.
127/9	0.15	57.96	Shale, grayish red, thinly laminated.
127/10	0.45	58.41	Alternate, very thin bedded fine to medium grained glauconitic sandstone, pale brown, and dark greenish gray laminated shale. Sandstone is current laminated.
126*	0.56	58.97	Dolomitic oolites, grayish orange, medium bed, with grayish red blotches; bottom 15 cm. are ferruginous oolites. Cross bedded. Unit is glauconitic.
125*	0.46	59.43	Glauconitic sandstone, grayish brown to greenish black, medium grained, very thin bedded. Current laminated; glauconite is very abundant.
			FAULT
124	1.98	61.41	Alternate laminated, grayish red shale and very thin bedded, very fine to fine grained, greenish gray sandstone. Sandstone becomes more glauconitic towards the top. Micro cross-bedding in opposite directions current laminated. Some horizons are flasered.
123/1*	0.38	61.79	Sandy dolomite, light gray with a grayish orange surface, very fine grained, thin bedded. Pure sandstone stringers in dolomite are slightly glauconite.
123/2	0.15	61.94	Sandstone, greenish gray, fine grained, very thin bedded with grayish red thinly laminated shale.

Unit	Thickness In Meters	Cumulative Thickness	Description
123/3	0.10	62.04	Sandstone, greenish gray to light brownish gray, fine grained, thin bedded. Current laminated with dark and light laminae.
123/4	0.33	62.37	Shale, light olive gray, laminated with very thin, very fine to medium grained sandstone stringers.
123/5*	0.94	63.31	Sandy dolomite, medium gray, very fine grained, very thin to medium bedded; weathered surface is grayish orange. Pure sandstone stringers with micro-cross-bedding. Dolomite looks laminated at the bottom with a light olive gray surface.
122	1.23	64.54	Alternate laminated shale and very thin bedded, very fine to medium grained, grayish red sandstone. Unit is mostly very thin bedded. Sandstone beds are ripple marked, current laminated with micro cross-bedding.
121/1	0.40	64.94	Sandstone, pale red, very fine grained, very thin to medium bedded with some laminated beds at the top.
121/2	0.05	64.99	Sandstone, greenish gray, fine to medium grained, very thin bed. Bed is lens shaped disappears in grayish red sandstone. Current laminated and glauconitic.
121/3	0.23	65.22	Sandstone, grayish red, very fine to fine grained, laminated to very thin bedded with intervening shale. 10% Shale.
121/4	0.20	65.42	Dolomite, medium gray, very fine, thin bedded with a grayish orange surface.
120	1.16	66.58	Alternate laminated grayish red shale and very thin bedded very fine to medium grained light greenish gray sandstone, with greenish gray shaly sandstone at the top. Some sandstone beds are glauconitic. 40% Shale Planolites on lower bedding of some beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
119/1*	1.18	67.76	Sandy dolomite, greenish gray, very fine grained, very thin bedded with occasional laminated shale. Weathered surface is grayish orange. Current laminated with alternate sandstone and glauconite laminae. Sandstone stringers are abundant.
119/2	1.00	68.76	Alternate dolomitic sandstone, very fine grained, very thin bedded and laminated shale, greenish gray; sandstone is more glauconitic at the bottom. 50% Shale. Current laminated.
119/3	1.83	70.59	Alternate very thin bedded, very fine grained sandstone and laminated shale; greenish gray with occasional very thin limestone beds which are dominant at the bottom. 50% Shale. Flaser bedding in some horizons.
119/4	1.57	72.16	Alternate thin to very thin bedded medium light gray, limestone and laminated greenish gray shale. Trilobite fragments in limestone.
119/5*	0.81	72.97	Laminated medium light gray limestone and greenish gray shale with occasional thin bedded limestone. Trilobite fragments especially at the bottom. Very fine planolites.
118/1*	0.30	73.27	Sandstone, pale red, fine grained with occasional medium grained glauconitic sandstone lenses, very thin bedded. Current laminated. Salt and pepper texture in glauconitic sandstone. Mud cracks.
118/2*	0.81	74.08	Alternate very thin bedded, medium dark gray limestone and laminated greenish gray shale. Weathered surface is greenish gray.

Unit	Thickness In Meters	Cumulative Thickness	Description
118/3*	1.42	75.50	Limestone, medium light gray, very fine, laminated at the bottom becoming thin bedded at the top with a grayish orange weathered surface, laminated shale is found at the bottom. A 3 cm. thick horizon full of trilobite fragments and intraclasts close to bottom. Intraclasts middle of unit. Sandstone stringers. Current laminated. Vertical worm burrows.
118/4	0.15	75.65	Sandstone, glauconitic, shaly greenish gray, very fine grained, thin bed.
117	0.40	76.05	Sandstone, grayish red, very fine to fine grained, very thin to thin bedded with occasional laminated shale. 15% Shale. Ripple marked, some beds are current laminated.
116	0.33	76.38	Laminated shale and sandstone, very fine grained, dark greenish gray. Flaser bedding.
115	0.30	76.68	Quartzitic sandstone, grayish orange pink to whitish, very fine grained, thin bedded. Fine internal glauconitic laminae. Jointed.
114/1*	0.30	76.98	Dolomite, medium dark gray, very fine, very thin to thin bedded, weathered surface is grayish orange. Current laminated.
114/2*	0.45	87.43	Sandstone, greenish gray, very fine to fine grained, laminated to very thin bedded, with pale brown shaly bedding planes. Fine internal glauconitic laminations.
113	4.72	82.18	Sandstone, grayish red, very fine to fine grained, very thin bedded with intervening laminated shale. Greenish gray glauconitic sandstone in the middle of unit. 10% Shale. Flaser bedding at the top of unit. Current laminated. _Planolites_ on lower bedding plane of some beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
112	1.90	84.08	Alternate laminated shale and very thin bedded, very fine to fine grained sandstone; greenish gray, with occasional calcare•us sandstone beds. 35% Shale Sandstone is glauconitic and current laminated.
111	0.23	84.31	Shale, grayish red, laminated with two laminated very fine grained sandstone beds.
110	0.40	84.71	Dolomite, medium light gray very fine, very thin to thin bedded. Current laminated with dark laminae. V•ry fine grained sandstone stringers.
109/1*	0.35	85.06	Dolomitic sandstone, greenish gray, very fine grained, thin bedded with two very thin horizons of laminated shale.
109/2	0.79	85.85	Sandstone, grayish red, very fine to fine grained, very thin to thin bedded with laminated shaly sandstone at the bottom. Ripple marked.
109/3	0.30	86.15	Calcareous siltstone, pale yellowish orange, laminated to very thin bedded occasional laminated shale.
109/4	1.68	87.83	Sandstone, pale red to grayish red, very fine to fine grained, thin bedded with occasional very thin and medium beds. Greenish gray bedding planes.
109/5	0.60	88.43	Sandstone, pale grown to grayish red, very fine to fine grained, very thin to thin bedded. Current laminated with fine glauconitic laminae; greenish gray weathered surface.
108/1	0.96	89.39	Alternate, very thin bedded, very fine grained sandstone and laminated shale, greenish gray with thin sandstone bed and shaly sandstone at the bottom. Flaser bedding at the top. Ripple marks in thin sandstone bed.

Unit	Thickness In Meters	Cumulative Thickness	Description
108/2	0.08	89.47	Silty shale, pale blue green, laminated.
107/1	0.66	90.13	Silty shale, grayish red, laminated with occasional thin sandstone beds becoming dominant at the bottom.
107/2	1.47	91.60	Alternate very thin bedded, very fine to fine grained sandstone and laminated shale, grayish red. 10% Shale. Ripple marked, <u>Planolites</u> on lower bedding plane of some beds. Mud cracks.
106	0.84	92.44	Shaly sandstone, greenish gray very fine to fine grained, laminated with occasional very thin sandstone beds.
105	0.38	92.82	Calcareous sandstone, pale red to brownish, very fine to fine grained, laminated at the bottom becoming thin bedded at the top. Pure sandstone stringers.
104	0.86	93.68	Laminated shale and sandstone, very fine grained, greenish gray. Sandstone is glauconitic. Flaser bedding.
103/1	0.30	93.98	Sandstone, pale brown, very fine to fine grained, very thin bedded. Fine internal glauconitic laminations. Ripple marks in one bed.
103/2	0.05	94.03	Laminated shale and glauconitic sandstone, very fine grained, greenish gray. 20% Shale. Flaser bedding.
103/3	0.35	94.38	Sandstone, grayish red, very fine to fine grained, laminated to very thin bedded. Medium to coarse grained sandstone lenses about 2 cm. thick and 20 cm. long. Current laminated. Occasional flaser bedding.
103/4	0.05	94.43	Sandstone, pale red, very fine grained, very thin bed. Bed wedges out.

Unit	Thickness in Meters	Cumulative Thickness	Description
103/5	0.35	94.78	Sandstone, grayish red, very fine to fine grained, very thin bedded with laminated greenish gray shale at the top, and shaly sandstone in the middle.
103/6	0.20	94.98	Glauconitic sandstone, dark greenish gray, very fine to fine grained, laminated with occasional very thin beds and grayish red shaly bedding planes.
103/7	0.25	95.23	Sandstone, grayish red, very fine grained, very thin bedded with occasional laminated greenish gray shaly sandstone.
103/8	0.20	95.43	Glauconitic sandstone, dark greenish gray, very fine to fine grained, laminated with grayish red shaly bedding planes. Current laminated with fine glauconitic laminae. Big fracture, beds distorted with drag folding and brecciation.
103/9	3.65	99.08	Alternate, greenish black sandstone and pale brown to grayish red sandstone, very fine to fine grained with occasional medium grained lenses, very thin bedded with some laminated beds. Grayish red shaly bedding planes. Current laminated, micro cross-bedding in opposite directions; glauconite is often concentrated in lenses. Salt and pepper texture in some beds.
103/10	0.10	99.18	Shale, greenish gray, laminated with occasional lam to very thin bedded, very fine grained sandstone. Sandstone is ripple marked. Shale at the top is burrowed.
103/11	1.68	100.86	Glauconitic sandstone, dark greenish gray, very fine to medium grained, laminated to very thin bedded with grayish red shaly bedding planes. Laminated shale at the top and bottom of unit. 10% Shale. Fine internal glauconitic laminae. <u>Planolites</u> are abundant in some beds.
103/12	0.84	101.70	Sandy shale, greenish gray, very fine to fine grained, laminated with occasional very thin sandstone beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
103/13	1.09	102.79	Alternate laminated dark greenish gray glauconitic sandstone and grayish red shaly sandstone, very fine grained with glauconitic medium grained horizons. Fine internal glauconitic laminations. Planolites on bedding plane of some beds.
103/14	1.98	104.77	Sandstone, dark greenish gray very fine to fine grained, very thin bedded alternating with light brownish, laminated shale. Planolites on lower bedding plane of some beds.
102	1.88	106.65	Alternate, laminated shale greenish gray and grayish orange very thin bedded, very fine grained sandstone. 50% Shale. Fine internal glauconitic laminations is sandstone. Planolites in some beds.
102/2	0.40	107.05	Glauconitic shaly sandstone, greenish gray, very fine to fine grained, very thin to thin bedded. Weathered surface is grayish orange.
101/1	0.30	107.35	Shaly sandstone, pale brown to reddish, fine to medium grained, medium bedded with greenish gray glauconitic sandstone lenses.
101/2	0.45	107.80	Sandstone, dark greenish gray, very fine to fine grained very thin bedded with intervening laminated shale. Flaser bedding. Weathered surface is grayish orange.
101/3	1.37	109.17	Glauconitic sandstone, dark greenish gray, very fine to medium grained, very thin bedded, with intervening laminated, grayish red sandy shale. Flaser bedding in the middle. Sandstone is current laminated with fine glauconitic laminae.
101/4	0.25	109.42	Sandy shale, grayish red thinly laminated with occasional laminated, very fine grained glauconitic sandstone.

Unit	Thickness In Meters	Cumulative Thickness	Description
101/5	0.05	109.47	Quartzitic sandstone, dark greenish gray, very fine grained very thin bed. Rusty weathered surface.
101/6	0.25	109.72	Sandy shale, grayish red, thinly laminated, very fine grained.
101/7	0.76	110.48	Sandy shale, pale yellowish brown very fine grained, thinly laminated with laminated sandstone at the bottom. Flaser bedding at the bottom. Weathered surface is grayish orange.
100/1	0.40	110.88	Alternate shale and sandstone very fine grained, laminated, medium dark gray. Grayish orange weathered surface.
100/2	1.47	112.35	Glauconitic shaly sandstone, pale olive, very fine grained, laminated, color becomes grayish red top 25 cm. Unit looks massive. Glauconitic is concentrated in lenses at the top.
100/3	0.60	112.95	Shaly sandstone, grayish red, very fine grained, laminated with dark greenish gray, glauconitic sandstone lenses, fine to medium grained.
100/4	1.83	114.78	Glauconitic shaly sandstone, light greenish gray, very fine grained, laminated with occasional very thin beds. _Planolites_ on lower bedding of some beds.
99	0.60	115.38	Alternate laminated shale and very thin bedded, very fine grained sandstone; dusky yellow. Flaser bedding. Rusty weathered surface.
98	0.86	116.24	Shaly glauconitic sandstone grayish red, fine grained, laminated to very thin bedded with a thin sandstone bed in the middle. Unit is greenish and more glauconitic at the bottom. Thin sandstone has dark yellowish orange weathered surface.

Unit	Thickness In Meters	Cumulative Thickness	Description
97*	0.56	116.80	Sandstone, dusky yellow, very fine to fine grained, thin bedded at the bottom becoming very thin bedded at the top with intervening laminated shale. 30% Shale. Fine Planolites on lower bedding plane of some beds.
96/1*	0.25	117.05	Glauconitic shaly sandstone, pale greenish yellow, fine to medium grained, laminated with very coarse grained lenses of quartz and hematite pellets at the top. Unit looks medium bedded. Dark yellowish orange weathered surface.
95	0.96	118.77	Sandstone, dusky yellow, very fine to fine grained, very thin bedded with intervening laminated shale. Current laminated; looks flasered. Some beds are bioturbated and full of Planolites.
94/1	0.35	119.12	Glauconitic shaly sandstone, pale greenish yellow, fine to medium grained, laminated.
94/2	0.35	119.47	Glauconitic shaly sandstone, pale brown, fine to medium grained, laminated with occasional very thin sandstone beds.
94/3	0.66	120.13	Sandy shale, dusky yellow, very fine to fine grained, laminated to very thin bedded with occasional laminated sandstone beds. Dark yellowish orange weathered surface. Unit is slightly glauconitic.
93/1	1.27	121.40	Shaly sandstone, glauconitic, dusky yellow, very fine to fine grained, laminated to very thin bedded. Unit is sandy shale at the bottom. Dark yellowish orange weathered surface. Laminated sandy shale looks like one thick bed.
93/2	0.10	121.50	Sandstone, light greenish gray, fine to coarse grained, thin bed. Rounded quartz grains.

Unit	Thickness In Meters	Cumulative Thickness	Description
92/1*	3.30	124.80	Sandstone, dusky yellow to pale brown, very fine to fine grained, very thin to medium bedded. Dark yellowish orange weathered surface. Fractured and jointed. Dissiminated mica. Planolites on lower bedding plane of some beds.
92/2	0.40	125.20	Shale, light olive gray, thinly laminated with very fine grained laminated sandstone at the bottom. Unit looks bioturbated. Rusty weathered surface.
92/3	1.22	126.42	Shaly sandstone, dusky yellow fine grained, very thin to thin bedded. Slightly glauconitic. Unit looks bioturbated. Rusty weathered surface.
92/4	0.80	127.22	Sandy shale, light olive gray, laminated, with occasional very thin bedded, very fine grained sandstone. Rusty weathered surface.
92/5	4.22	131.44	Sandstone and shaly sandstone, light olive gray, very fine to fine grained, very thin to thin bedded. Many beds look bioturbated. Some beds are slightly glauconitic. Rusty weathered surface. Fractured and jointed.
92/6	0.71	132.15	Glauconitic shaly sandstone, light greenish gray, very fine grained, very thin to thin bedded. Looks like one thick bed. Rusty weathered surface.
92/7	0.60	132.75	Sandstone, pale yellowish brown, very fine grained, laminated to very thin bedded. Fine internal glauconitic laminae.
91/1	0.86	133.61	Alternate laminated shale and sandstone, very fine grained, grayish red; occasional very thin bedded sandstone.
91/2	0.15	133.76	Shale, greenish gray, thinly laminated with some very thin bedded silty shale.

Unit	Thickness In Meters	Cumulative Thickness	Description
91/3	0.20	133.96	Sandstone, dusky yellow, very fine grained, very thin bedded with intervening laminated shale. 10% Shale Current laminated.
91/4	0.15	134.11	Shale, greenish gray, thinly laminated. Flakey and friable.
91/5	0.08	134.19	Siltstone, greenish gray, very thin bedded with 2 cm. thick horizon of shale. Rusty weathered surface.
91/6	0.45	134.62	Shale, medium bluish gray, thinly laminated with a 3 cm. thick of siltstone in the middle. Flakey and friable.
91/7	0.20	134.82	Silty shale, light olive gray, laminated. Unit looks thin bedded.
91/8	1.50	136.32	Shale, grayish olive, thinly laminated with occasional laminated to very thin bedded siltstone.
90*	7.36	143.68	Limestone, medium gray, microcrystalline, thick to very thick bedded; very pale orange weathered surface. Honeycomb weathering due to replacement by dolomite. Intraclasts are abundant. Deeply weathered and partly covered by overlying shale.
89	1.50	145.18	Shale, grayish red, thinly laminated. Flakey and friable.
88*	8.12	153.30	Limestone, medium gray, micro-crystalline, thick to very thick bedded; very pale orange weathered surface. Honeycomb weathering due to partial replacement by dolomite. Deeply weathered and partially covered by overlying shale.
87/1	4.82	158.12	Sandstone, very fine grained very thin bedded with intervening laminated shale and siltstone; original color is marked by deep weathering colors of dark yellowish orange to moderate yellowish brown. Not very well exposed.

Unit	Thickness In Meters	Cumulative Thickness	Description
87/2	0.62	158.74	Sandstone, pale yellowish brown, very fine grained, very thin bedded with intervening light olive gray laminated shale. 10% Shale. Mica flakes could be recognized in sandstone. Planolites are abundant.
87/3	1.00	159.74	Sandstone, grayish red, very fine to fine grained, very thin bedded with intervening laminated shale. 10% Shale Sandstone is current laminated.
87/4	0.25	159.99	Alternate, very thin bedded very fine to fine grained, moderate yellowish brown sandstone and dark greenish gray, laminated shale. Sandstone beds wedge out.
86*	0.75	160.74	Dolomite, medium gray, micro-crystalline, very thin to thin bedded. Very pale orange weathered surface. Mud cracks?
85	0.66	161.40	Sandy dolomite, dark gray, micro-crystalline, very thin bedded. Current laminated with dark and light laminae.
84/1	0.43	161.83	Dolomite, sandy, medium light gray, very fine grained medium bedded with few thin beds.
84/2	0.05	161.88	Shaly siltstone, greenish gray laminated.
84/3	0.56	162.44	Quartzitic sandstone, grayish pink to pale red, very fine grained, laminated to thin bedded. Current laminated. Trilobite tracks at the bottom of unit.
83/1	0.30	162.74	Sandstone, grayish red, very fine grained, very thin bedded with intervening laminated shale. 10% Shale. Ripple marked. Flaser bedding.
83/2	0.15	162.89	Sandstone, pale red, very fine grained, thin bed. Current laminated.

Unit	Thickness In Meters	Cumulative Thickness	Description
83/3	0.68	163.57	Alternate very thin to thin bedded sandstone and laminated to very thin bedded shaly sandstone, very fine to fine grained, grayish red. Current laminated, some internal laminae are shaly. Planolites in some beds.
82/1	0.30	163.87	Silty shale, dark greenish gray laminated. Calcite veins 1 mm. thick.
82/2	0.20	164.07	Shale, dark gray, thinly laminated, with a very thin dolomite bed at the top.
81	0.60	164.67	Sandstone, very pale orange to light olive gray, very fine grained, thin bedded at the bottom to laminated at the top. Current laminated; slightly glauconitic.
80	0.38	165.05	Calcareous shale, pale olive, laminated.
79/1*	0.45	165.50	Sandstone, very pale orange at the top and pale red at the bottom, very fine grained, very thin bedded. Current laminated.
79/2*	0.35	165.85	Dolomite, pale red, micro-crystalline, medium bed. Current laminated. Fractured and jointed in some places.
78/1	0.15	166.00	Alternate laminated, shale and sandstone, very fine grained, grayish red. Looks flasered.
78/2	0.10	166.10	Limestone, grayish orange, micro-crystalline, thin bed. Mud cracks, current laminated.
78/3	0.20	166.30	Laminated shale and sandy shale, grayish red, very fine grained. Flaser bedding.
77/1*	0.60	166.90	Quartzitic sandstone, pale red becoming lighter at the top, very fine grained, thin to medium bedded.

Unit	Thickness In Meters	Cumulative Thickness	Description
77/2	1.78	168.68	Sandstone, grayish red, very fine grained, thin to very thin bedded with occasional laminated shaly sandstone. Ripple marks, current laminated; flaser bedding. Some beds are bioturbated. Thin sandstone beds wedge out.
77/3	0.18	168.86	Sandstone, greenish gray, very fine grained, very thin bedded with intervening laminated shale. 10% Shale
77/4	0.99	169.85	Sandstone, grayish red, very fine grained, thin bedded. Current laminated; micro cross-bedding.
77/5	0.35	170.20	Sandstone, grayish red, very fine grained, very thin bedded, with intervening laminate shale and shaly sandstone. 10% Shale. Fine micro-cross-bedding. Sandstone slightly glauconitic. Flaser bedding.
77/6*	0.66	170.86	Quartzitic sandstone, pale red, very fine grained, very thin bedded with greenish gray bedding planes. Ripple marked, shaly internal laminations look like clasts.
77/7	0.76	171.62	Sandstone, grayish red, very fine grained, very thin to thin bedded. Most of the beds are bioturbated and full of burrow casts with disruption of bedding. Beds which are not burrowed might indicate rapid deposition.
76/1	0.88	171.70	Laminated very fine sandstone and shale, greenish gray. Flaser bedding.
76/2	0.08	171.78	Shale, greenish gray, thinly laminated. Friable.
76/3	0.10	171.88	Sandstone, grayish orange, very fine grained, very thin bedded.
76/4	0.10	171.98	Shaly sandstone, grayish brown very fine grained, laminated. Slightly glauconitic.

Unit	Thickness In Meters	Cumulative Thickness	Description
75/1	0.25	172.23	Sandstone, grayish red, very fine grained, laminated to thin bedded. Micro cross-bedding, current laminated.
75/2	0.05	172.28	Sandstone, grayish orange, very fine grained, thin bed.
75/3	0.05	172.33	Laminated, very fine grained sandstone and shale, grayish red. 30% Shale Flaser bedding.
75/4	0.38	172.71	Sandstone, pale red to light brown, very fine grained, thin bedded. Micro-cross-bedding. Current laminated with alternate light and dark laminae.
74/1	1.62	174.33	Sandstone, pale red to grayish red, very fine grained, very thin to thin bedded. Current laminated. <u>Planolites</u> on lower bedding plane of some beds. Fractured and jointed.
74/2	0.20	174.53	Laminated, very fine grained sandstone and shale, grayish red. 50% Shale. Flaser bedding.
74/3	0.08	174.61	Sandstone, pale brown, very fine grained, very thin bedded. Micro cross-bedding, wavy internal laminae.
74/4	0.25	174.86	Laminated, very fine grained sandstone and shale, grayish red. Sandstone beds are ripple marked, flaser bedding.
74/5	1.57	176.43	Sandstone, grayish red, very fine grained, very thin bedded with occasional thin beds alternating with laminated shale. 50% Shale Flaser bedding at the bottom. Some beds are dioturbated. Horizontal and vertical worm burrows. Planolites in some beds.
73	0.58	177.01	Shaly siltstone, pale olive, laminated. Slightly calcareous.

Unit	Thickness In Meters	Cumulative Thickness	Description
72	1.16	178.17	Sandstone, grayish orange pink, very fine grained, thin bedded. Glauconitic or chloritic at the bottom.
71/1	0.15	178.32	Shale, grayish olive, laminated.
71/2	0.25	178.57	Sandy shale, grayish red, very fine grained, laminated. Some laminae are glauconitic.
71/3	0.25	178.82	Calcareous siltstone, pale olive, very thin bedded at the bottom becoming laminated at the top.
71/4	0.20	179.02	Shale, grayish green, laminated. Friable.
71/5	0.20	179.22	Siltstone, grayish green, laminated to very thin bedded. Unit looks like one medium bed.
71/6	1.21	180.43	Shale, grayish green, thinly laminated. Flakey and friable.
70/1	3.07	183.50	Dolomite, medium dark gray, mirco-crystalline, very thin to thin bedded, very pale orange weathered surface. Very fine grained sandstone stringers and lenses in dolomite beds. Unit is partly covered.
70/2	0.60	184.10	Shale, medium dark gray, laminated to very thin bedded, with very thin dolomite beds. Mud cracks in some dolomite beds.
70/3*	0.20	184.30	Sandstone, grayish orange, very fine grained, very thin bedded. Grayish blotches on surface. Halite casts.
70/4	1.22	185.52	Dolomite, medium dark gray cryptocrystalline, very thin to thin bedded with laminated shale. 20% Shale Very fine grained sandstone stringers.
69	1.06	186.58	Quartzitic sandstone, yellowish gray to pale olive, very fine grained, thin to medium bedded. Fine internal irregular laminae. Slightly glauconitic. Limonitic blotches on surface.

Unit	Thickness In Meters	Cumulative Thickness	Description
68/1*	1.16	187.74	Sandstone, grayish red, very fine grained, very thin to thin bedded with intervening laminated shale, flakey and friable. 40% Shale Micro cross-bedding. Planolites are abundant in sandstone beds. Some beds are bioturbated.
68/2	0.08	187.82	Sandstone, pale red, very fine grained, thin bed. Greenish and reddish internal laminae.
67/1	0.08	187.90	Silty shale, grayish orange, laminated, with grayish bedding planes.
67/2	0.40	188.30	Sandstone, grayish red, very fine grained, very thin bedded with occasional thin beds and intervening laminated shale. 50% Shale Flaser bedding. Sandstone has a grayish range weathered surface.
66	1.52	189.82	Sandstone, grayish red, very fine grained, thin bedded with occasional very thin and medium beds. Ripple marked. Beds in the middle are bioturbated.
65/1	0.23	190.05	Shale, grayish red, laminated with very thin bedded, very fine grained sandstone at the top.
65/2	0.10	190.15	Sandstone, light brown, very fine grained, thin bed. Fine internal wavy laminations; vesicles, 2 mm. in diameter.
65/3	0.10	190.25	Shale, grayish red, thinly laminated. Flakey.
65/4	0.08	190.33	Sandstone, light brown, very fine grained, very thin bedded. Current laminated with dark and light laminae.
65/5	0.18	190.51	Shale, grayish red, thinly laminated. Flakey and friable.

Unit	Thickness In Meters	Cumulative Thickness	Description
65/6	1.22	191.73	Sandstone, grayish red, very fine grained, very thin bedded with intervening laminated shale. 40% Shale. Ripple marked. Current laminated.
64	0.96	192.69	Shale, grayish red, laminated. Flakey and friable.
63	0.63	193.32	Shale, grayish olive, thinly laminated with laminated very fine grained shaly sandstone. 60% Shale.
62/1	0.30	193.62	Calcareous siltstone, grayish yellow, very thin to laminated with 3 cm. thick dark gray shale
62/2	0.60	194.22	Sandstone, grayish red, very fine grained, very thin to thin bedded with intervening laminated shale. 15% Shale Mud cracks. <u>Planolites</u> on lower bedding plane of some beds.
61	0.91	195.13	Shale, grayish red, thinly laminated, with occasional very thin bedded very fine grained sandstone.
60	0.45	195.58	Sandstone, grayish red, very fine grained, very thin bedded with intervening laminated shale. 10% Shale. Flaser bedding. Mud cracks. Sandstone slightly glauconitic.
59	0.71	196.29	Sandstone, light brown, very fine grained, thin bedded, with shaly bedding planes. Current laminated. <u>Planolites</u> on lower bedding plane of some beds.
58/1*	0.25	196.54	Sandstone, dark grayish red, very fine grained, very thin bedded with occasional laminated shale. 10% Shale Flaser bedding. <u>Planolites</u> in some beds.
58/2	0.41	196.95	Sandstone, grayish red, very fine grained, very thin to thin bedded, with greenish gray bedding planes. Ripple marks.

Unit	Thickness In Meters	Cumulative Thickness	Description
57/1	0.08	197.03	Sandstone, greenish gray to very pale orange, very fine grained, thin bed.
57/2	0.25	197.28	Sandstone, dusky yellow, very fine grained, very thin bedded with occasional laminated shale. 5% Shale. Sandstone is glauconitic.
57/3	0.15	197.43	Sandstone, greenish gray, very fine grained, very thin bedded with intervening laminated shale. 5% Shale. Sandstone is slightly glauconitic.
57/4	0.35	197.78	Sandstone, greenish gray, very fine grained, very fine grained, very thin bedded with laminated shaly sandstone at the bottom. Sandstone becomes more glauconitic towards bottom of unit.
56	0.91	198.69	Sandstone, grayish red, very fine grained, very thin to thin bedded with occasional laminated shale. Mud cracks in several beds, greenish gray bedding planes.
55/1	0.08	198.77	Shaly sandstone, greenish gray, very fine grained, laminated. 20% Shale. Planolites under some beds.
55/2	1.57	200.34	Sandstone, grayish red, very fine grained, very thin bedded with occasional laminated shale. 20% Shale Mud cracks. Planolites under some beds. Flaser bedding lower 25 cm.
55/3	0.60	200.94	Glauconitic sandstone, dark, greenish gray, very fine grained very thin bedded, with intervening laminated grayish red shale. 25% Shale. Ripple marked; flaser bedding. Planolites.

Unit	Thickness In Meters	Cumulative Thickness	Description
54/1*	0.96	201.90	Sandstone, grayish orange pink, very fine grained, thin bedded with occasional very thin beds. Ripple marked; current laminated with shale and glauconitic internal laminae.
54/2	0.23	202.13	Glauconitic sandstone, greenish gray, very fine grained, very thin to thin bedded. Planolites on lower bedding plane of some beds. Grayish orange weathered surface.
53/1	0.35	202.48	Sandstone, pale olive to olive gray, very fine grained, laminated with occasional very thin beds and intervening laminated shale. 10% Shale. Flaser bedding. Planolites on lower bedding plane of some beds.
53/2	0.79	203.27	Sandstone, yellowish gray, very fine grained, very thin to thin bedded with occasional laminated shale. Unit is bioturbated planolites on lower bedding plane.
52	0.71	203.98	Sandstone, grayish red, very fine grained, very thin to thin bedded, some beds are shaly. Mud cracks; current laminated with internal shale laminae.
51	3.02	207.00	Shale, grayish red, thinly laminated. Flakey and friable.
50*	2.38	209.38	Sandstone, grayish red, very fine grained, very thin to thin bedded with shaly bedding planes. Mud cracks; current laminated with very fine shale lenses. Ripple marks. Planolites on some bedding planes. Beds at the top are vuggy.
49	2.57	211.95	Silty shale, grayish red, laminated becoming more silty at the middle with a grayish orange siltstone bed 13 cm. thick in the middle. Friable; unit looks massive.
48	1.09	213.04	Sandstone, pale brown, very fine grained, very thin bedded with shaly bedding planes. Current laminated; mud cracks. Planolites.

Unit	Thickness In Meters	Cumulative Thickness	Description
48	1.09	213.04	Sandstone, pale brown, very fine grained, very thin bedded with shaly bedding planes. Current laminated; mud cracks. Planolites.
47	0.89	213.93	Sandstone, grayish red, very fine grained, laminated with intervening shale becoming dominant at the bottom. Flaser bedding; current laminated. Ripple marked.
46/1	0.55	214.48	Shale, grayish red, laminated with occasional laminated, very fine grained shaly sandstone. Flakey and friable.
46/2	0.50	214.98	Shale, dark greenish gray at the bottom and grayish red at the top, thinly laminated.
46/3	1.17	216.15	Silty shale, dark greenish gray laminated. Fecal pellets on bedding planes.
46/4	0.40	216.55	Sandstone, grayish orange pink, very fine grained, very thin bedded with intervening greenish gray shale. Ripple marked. COVERED?
			FAULT
45/1	1.47	218.02	Sandstone, pale yellowish brown to very pale orange, very fine grained, thin bedded with occasional very thin and medium beds. Jointed.
45/2	0.66	218.68	Shale, light greenish gray, thinly laminated. Flakey and friable.
45/3	2.18	220.86	Sandstone, pale yellowish brown to very pale orange, very fine grained, thin bedded mostly with some very thin and medium beds. Jointed.

Unit	Thickness In Meters	Cumulative Thickness	Description
44/1	1.02	221.88	Sandstone, pale brown to grayish red, laminated, very fine grained, alternating with thinly laminated shale. 50% Shale. Flaser bedding. Shale dominant at bottom.
44/2	0.50	222.38	Shale, greenish gray, laminated, alternating with laminated dark yellowish orange, very fine grained sandstone. 60% Shale. Flaser bedding. Shale is dominant at the top of unit.
43	0.35	222.73	Shaly sandstone, light olive gray, very fine grained, laminated to very thin bedded with grayish orange, thin sandstone bed at the top. Ripple marked.
42/1	1.12	223.85	Sandstone, yellowish gray, very fine grained, thin to medium bedded with pale olive bedding planes. Ripple marked. <u>Planolites</u> are not abundant. Mud cracks.
42/2	0.55	224.40	Sandstone, very pale orange, very fine grained, very thin bedded with occasional laminated shale. 5% Shale.
42/3	1.62	226.02	Quartzitic sandstone, pale red to grayish orange, very fine grained, medium bedded with occasional thin beds. Fine pale red and grayish orange internal laminations. Slightly glauconitic at the top.
41	2.13	228.15	Sandstone, grayish red, very fine grained, laminated to very thin bedded with shaly bedding planes. Current laminated; ripple marks; flaser bedding bottom 38 cm. <u>Planolites</u>.
40	1.57	229.72	Sandstone, pale brown to grayish red, very fine grained, medium to thin bedded with occasional very thin bedded sandstone and laminated shale. Mud cracks; ripple marks; current laminated.

Unit	Thickness In Meters	Cumulative Thickness	Description
39	0.66	230.38	Shale, grayish red, thinly laminated, silty at the top. Flakey and friable.
38	1.78	232.16	Sandstone, grayish red, very fine grained, very thin to thin bedded with intervening laminated shale. 30% Shale. Ripple marked; mud cracks. Planolites.
37/1	0.50	232.66	Silty shale, dusky yellow, laminated. Unit looks medium bedded.
37/2	1.17	233.83	Sandstone, yellowish gray to light greenish gray, very fine grained, very thin to thin bedded with pale olive bedding planes. Fractured and jointed. Ripple marks; current laminated. Planolites, some beds are bioturbated.
36/1	0.40	234.23	Calcareous siltstone, pale greenish yellow to grayish yellow, laminated. Transverse calcite veins - 2 mm. thick.
36/2	2.03	236.26	Shale, greenish gray, thinly laminated. Flakey and friable, calcite veins 2 mm. thick.
35	1.42	237.68	Silty limestone, grayish yellow, laminated to very thin bedded, with few dark very thin bedded dolomite. Mud cracks; halite casts. Fine internal laminae in dolomite. Unit is disturbed.
34	0.76	238.44	Calcareous shale, dusky yellow, laminated.
			FAULT
33/1	0.30	238.74	Sandstone, grayish orange, very fine grained, medium bed. Fractured and jointed.
33/2	0.81	239.55	Calcareous shale, dusky yellow laminated with very thin bedded very fine grained sandstone in the middle. Looks flasered in the middle.
32	1.00	240.55	Sandstone, dusky yellow to light brownish, very fine grained very thin to thin bedded with a medium gray, very thin to thin bedded dolomite wedge in the middle.

Unit	Thickness In Meters	Cumulative Thickness	Description
			Laminated calcareous shale at the same level with dolomite. Ripple marked. Flaser bedding at the top of unit.
31	1.00	241.55	Shaly dolomite, medium gray very thin bedded with intervening calcareous shale, dusky yellow, laminated. Occasional very thin very fine grained sandstone beds. Dolomite breaks into small cubes and chips.
30/1	0.86	242.41	Sandstone, dusky yellow, very fine grained, very thin to thin bedded. Some beds are bioturbated. Fractured and jointed. Limonitic weathered surface.
30/2	0.76	243.17	Sandstone, glauconitic, dark greenish gray, very fine grained very thin to thin bedded. Planolites 2 mm. wide, 2 cm. long. Sole like marks on some beds. Jointed.
29	0.71	243.88	Shale, grayish red, laminated with few very thin bedded, very fine grained sandy shale. Unit has a lighter color at the top. Friable.
28/1	0.10	243.98	Quartzitic sandstone, pale brown, very fine grained, thin bed. Current laminated.
28/2	0.15	244.13	Shale, thinly laminated, greenish gray at the bottom and grayish red at the top.
28/3	0.10	244.23	Sandstone, greenish gray, very fine grained, very thin bedded. Fine greenish laminae at the top and reddish laminae at the bottom.
28/4	0.40	244.63	Sandstone, glauconitic, grayish red, very fine grained very thin bedded with occasional thin beds and intervening laminated shale becoming dominant at the top. Planolites in some beds.
27/1	0.46	245.09	Sandstone, grayish orange, very fine grained, thin to medium bedded. Current laminated. Jointed and fractured.

Unit	Thickness In Meters	Cumulative Thickness	Description
27/2	0.25	245.34	Sandstone, grayish yellow to pale brown, very fine grained, very thin bedded with greenish gray, shaly bedding planes. Shale slightly metromorphosed by folding.
26	0.35	245.69	Sandstone, grayish red, very fine grained, very thin bedded, with intervening thinly laminated shale. 10% Shale. Ripple marks. _Planolites_.
25	1.16	246.85	Sandstone, pale red to pale brown, very fine grained, thin to medium bedded with limonitic surfaces. Mud cracks; ripple marks; current laminated. _Planolites_ in some beds in the middle 1.5 cm. wide.
24/1	0.15	247.00	Sandstone, pale red to pale brown, very fine grained, very thin to thin bedded with some laminated shale. Mud cracks; ripple marks. Worm burrows.
24/2	0.20	247.20	Shale, grayish red, thinly laminated alternating with very thin bedded, very fine grained sandstone. 60% Shale. Mud cracks; _Planolites_.
			SMALL FAULT
24/3	0.35	247.55	Alternate, laminated shale and very fine grained, very thin bedded sandstone, grayish red. 50% Shale.
24/4	0.20	247.75	Shale, grayish red, thinly laminated with occasional laminated, very fine grained shaly sandstone. Calcite veins 2 mm. thick. Flakey and friable.
24/5	0.66	248.41	Sandstone, grayish red, very fine grained, very thin bedded with occasional thin beds alternating with laminated shale. 35% Shale. Mud cracks; ripple marks; current laminated.

Unit	Thickness In Meters	Cumulative Thickness	Description
24/6	0.25	248.66	Shale, grayish red, thinly laminated. Flakey and friable. Calcite veins.
24/7	0.35	249.01	Sandstone, grayish orange, very fine grained, very thin to thin bedded with grayish red shaly bedding planes. Ripple marks.
23/1	1.22	250.23	Silty shale, grayish red, laminated with two very thin very fine grained sandstone beds at the top. Sandstone beds, ripple marked and current laminated.
23/2	0.40	250.63	Shale, greenish gray, thinly laminated alternating with very thin bedded, very fine grained grayish yellow sandstone. Shale is dominant at the top.
23/3	0.20	250.83	Siltstone, dusky yellow, very thin bedded. A 5 cm. thick greenish gray, very fine grained sandstone bed at the bottom. Weathers to small cubes.
22/1	2.18	253.01	Sandstone, grayish red, very fine grained, very thin bedded alternating with laminated shale. 40% Shale Mud cracks; ripple marks. <u>Planolites</u>. Flaser bedding.
22/2	0.15	253.16	Shale, dark greenish gray, laminated with sandy shale very fine grained. Shale has a shiny luster.
22/3	0.30	253.46	Sandstone, grayish red, very fine grained, very thin bedded alternating with laminated shale. Flaser bedding; <u>Planolites</u>.
21	0.50	253.96	Sandstone, pale brown to grayish red, very fine grained, very thin to thin bedded with shaly bedding planes. Current laminated. Some beds wedge out.

Unit	Thickness In Meters	Cumulative Thickness	Description
20	1.57	255.53	Sandstone, grayish red, very fine grained, very thin bedded alternating with laminated shale; sandstone is dominant in the middle of unit. Occasional greenish gray laminated shale. 30% Shale. Flaser bedding top and bottom of unit, ripple marks; Planolites; fecal pellets on bedding planes.
19/1	0.86	256.39	Sandstone, pale red, light greenish gray at the top, very fine grained, very thin to thin bedded. Ripple marked; some beds are lenses 0.75 - 1.00 mm. long.
19/2	0.35	256.74	Sandstone, grayish red, very fine grained, very thin bedded alternating with laminated shale. 25% Shale. Flaser bedding; ripple marks; mud cracks; current laminated.
18	0.96	257.70	Sandstone, grayish red, very fine grained, very thin bedded with intervening laminated shale. 40% Shale. Flaser bedding.
17/1	0.08	257.78	Sandstone, pale brown, very fine grained, very thin bedded, with shaly bedding planes. Ripple marked; current laminated.
17/2	0.10	257.88	Sandstone, grayish red, very fine grained, laminated alternating with laminated shale. 30% Shale. Flaser bedding.
17/3*	0.45	258.33	Sandstone, pale red to grayish red, very fine grained, very thin to thin bedded, with shaly bedding planes. Current laminated.
16	0.71	259.04	Sandstone, pale red to grayish orange, very fine grained, very thin bedded with grayish red, laminated shale. Light greenish gray sandstone bed at the top. 5% Shale. Ripple marked.

Unit	Thickness In Meters	Cumulative Thickness	Description
15/1	0.66	259.70	Sandstone, grayish red, very fine grained, very thin bedded alternating with laminated shale and shaly sandstone. Flaser bedding; ripple marked; current laminated.
15/2	0.08	259.78	Shale, laminated alternating with very fine grained sandstone, grayish red. Flaser bedding.
14	0.76	260.54	Sandstone, pale red to pale brown, very fine grained, very thin bedded with shaly bedding planes. 5% Shale. Ripple marked; mud cracks; flasered at the bottom; planolity.
13/1	0.30	260.84	Shale, grayish red, thinly laminated alternating with laminated, very fine grained sandstone. 60% Shale. Flaser bedding.
13/2	0.20	261.04	Shale, greenish gray, laminated alternating with laminated very fine grained sandstone. 60% Shale. Flaser bedding.
12	0.76	261.80	Sandstone, pale red to grayish red, very fine grained, very thin to thin bedded with shaly bedding planes. Ripple marked; fine shale internal laminae in some beds. *Planolites* 1 - 2 cm. wide. Unit looks massive. Jointed.
11	0.55	262.35	Sandstone, grayish red, very fine grained, laminated with occasional very thin beds alternating with laminated shale. 40% Shale. Flaser bedding.
10/1	0.35	262.70	Sandstone, grayish red, very fine grained, very thin to thin bedded with occasional laminated greenish gray shale and sandstone. 5% Shale. Ripple marked. Some beds are bioturbated.

Unit	Thickness In Meters	Cumulative Thickness	Description
10/2	0.55	263.25	Shale, grayish red, laminated, alternating with laminated, very fine grained sandstone. 50% Shale. Flaser bedding. Sandstone slightly glauconitic. Small normal fault.
9/1*	0.45	263.70	Sandstone, pale brown at the bottom becoming light greenish gray at the top, very fine grained, thin to very thin bedded with one medium bed. Unit looks modular at the top due to the presence of shale. Slightly glauconitic at the bottom. Looks bioturbated with very short vertical burrows. (Scoyenia).
9/2	0.50	264.20	Sandstone, grayish red, very fine grained, very thin bedded with thin beds at the top and bottom alternating with laminated shale. 30% Shale. Flaser bedding; mud cracks. Planolites in some beds.
8	0.91	265.11	Sandstone, grayish red to pale brown, very fine grained, very thin bedded alternating with laminated shale which is abundant at the top. 30% Shale. Flaser bedding; ripple marked. Planolites. Very fine calcite veins.
7	0.81	265.92	Sandstone, pale red, very fine grained, medium bedded at the bottom becoming thin bedded at the top. Ripple marked; current laminated. Limonitic blotches on the surface.
6/1	0.40	266.32	Sandstone, greenish gray, very fine grained, laminated alternating with thinly laminated shale with shale dominant top 5 cm. 10% Shale Flaser bedding. Small folds in unit.
6/2	0.15	266.47	Sandstone, grayish yellow, very fine grained, very thin bedded with occasional laminated shale.
5/1	1.05	267.52	Quartzitic sandstone, grayish yellow to pale olive at the top, fine grained; thin bedded with occasional very thin and medium beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
			Current laminated, laminae have a limonitic color. Unit looks thick bedded.
5/2*	0.28	267.80	Sandstone, moderate orange pink, very coarse to medium grained, medium bed. Large scale cross bedding. Quartz grains are rounded; friable.
5/3	0.60	268.40	Quartzitic sandstone, grayish orange to pale olive, very fine grained, thin to medium bedded. Pale green to reddish internal laminations. Unit looks thick bedded.
5/4 *	0.30	268.70	Sandstone, grayish red, very fine grained, thin to medium bedded. Mud cracks; dark and light internal laminations; bioturbated.
4/1	0.15	268.85	Silty shale, dark greenish gray laminated. Friable.
4/2	0.10	268.95	Silty shale, grayish red, laminated. Friable.
4/3	0.10	269.05	Silty shale, dark greenish gray, laminated. Friable.
4/4	2.84	271.89	Silty shale, grayish red, laminated. Friable.
4/5	1.06	272.95	Shaly siltstone, grayish red, laminated. Unit looks medium bedded.
3/1	1.83	274.78	Sandstone, grayish red, very fine grained, very thin to thin bedded with occasional laminated shale. 5% Shale. Ripple marked; mud cracks, alternate dark brown and light internal laminae of shale and sandstone.
2/1	1.42	276.20	Silty shale, grayish red, laminated. Very fine calcite veins parallel and diagonal to bedding.

Unit	Thickness In Meters	Cumulative Thickness	Description
2/2	0.66	276.86	Siltstone, grayish red, with light greenish gray laminae at the top, very thin to thin bedded.
			FAULT
1/1	1.00	277.86	Sandstone, grayish red, very fine grained, very thin to thin bedded with laminated silty shale at the top. Calcite veins parallel and diagonal to bedding. Asymumetrical fold.
1/2	0.96	278.82	Silty shale, grayish red, laminated.
1/3	1.78	280.60	Sandstone, grayish red, very fine grained, very thin to thin bedded, occasional laminated beds. Mud cracks. Current laminated. Shaly bedding planes.
1/4	1.78	282.38	Shale, grayish red, laminated alternating with very fine grained, laminated shaly sandstone. 60% Shale. Flakey and friable.
1/5	0.40	282.78	Shale, dark greenish gray, laminated. Friable.
1/6	2.28	285.05	Silty shale, grayish red, laminated with intervening very fine grained, very thin bedded sandstone with occasional, laminated dark greenish gray silty shale.
1/7*	1.27	286.33	Sandstone, grayish red, very fine grained, very thin bedded with shaly bedding palnes. Halite casts; mud cracks.
			COVERED?
			WHITE OAK MOUNTAIN FAULT

PINE RIDGE - CLINTON SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			COVERED AND FAULTED
11/1*	1.65	1.65	Sandstone, grayish olive, medium to coarse grained, thin to medium bedded with a rusty weathered surface.
11/2	1.75	3.40	Sandstone, pale olive, very fine to medium grained, very thin bedded with occasional thin beds. Jointed.
11/3	0.28	3.68	Sandstone, light olive gray, fine to medium grained, very thin to thin bedded with light brownish gray bedding planes. Beds look modular due to weathering.
11/4	0.13	3.81	Sandstone, pale yellowish brown to dark greenish gray, fine grained with lenses of medium to coarse grained sandstone, very thin bedded.
11/5	0.55	4.36	Sandstone, pale yellowish brown, fine to medium grained, laminated to very thin bedded with intervening clay due to weathering. Sandstone beds have rusty reddish surfaces.
11/6	0.20	4.56	Sandstone, light olive gray, fine grained, medium bedded but wedges out and becomes thin to very thin bedded laterally. Beds are fractured and jointed with rusty colored surfaces.
11/7*	1.20	5.76	Sandstone, greenish gray, fine to medium grained, very thin to thin bedded alternating with bluish gray laminated shale which is dominant at the bottom and decreases upward. Coarse grained sandstone is at the top. 20% Shale. Planolites in some sandstone beds.
10/1	0.08	5.84	Sandstone, pale olive, fine to medium grained, thin bedded. Rusty weathered surface.

Unit	Thickness In Meters	Cumulative Thickness	Description
10/2*	0.55	6.39	Sandstone, light olive gray to grayish red, coarse to very coarse grained, thin bedded. Conglomeritic horizons with white and yellowish rounded quartz grains.
10/3	0.33	6.72	Sandstone, greenish gray and dark greenish gray, medium to coarse grained, very thin bedded with occasional laminated shale, pale yellowish orange and pale olive. Sandstone beds have a rusty weathered surface.
10/4	0.55	7.27	Sandstone, grayish red and grayish olive, fine to medium grained interbedded with coarse grained grayish red sandstone beds, thin to very thin bedded.
9/1	0.70	7.97	Sandstone, grayish orange with a greenish tinge, fine grained, very thin bedded with laminated shale at the top. 5% Shale.
9/2	2.35	10.32	Sandstone, pale olive, medium grained with occasional fine and coarse grained beds, very thin to medium bedded, with rusty weathered surfaces. Medium bedded sandstone wedge out and become very thin bedded laterally. *Planolites* on upper bedding of some beds.
8*	1.40	11.72	Sandstone, greenish gray, fine grained, medium to thick bedded, with 3 cm. thick lens of conglomerate of very coarse quartz and black pebbles.
7	2.75	14.47	Alternate laminated shale and very fine grained, very thin bedded sandstone, light bluish gray. 60% Shale. Sandstone beds are ripple marked; some beds have *Planolites*.
6/1	0.33	14.80	Sandstone, glauconitic, pale olive to greenish gray, fine grained, medium bedded, with rusty weathered surface. Bed wedges out, fine ripple marks.
6/2	0.18	14.98	Shale, medium bluish gray, thinly laminated, flakey and friable.

Unit	Thickness In Meters	Cumulative Thickness	Description
6/3	0.35	15.33	Sandstone, glauconitic, pale olive, fine grained, thin bedded.
5	1.05	16.38	Alternate thinly laminated shale and very thin bedded, very fine grained sandstone, medium bluish gray. 20% Shale. Some laminated beds are reddish.
4*	0.60	16.98	Sandstone, medium bluish gray, fine grained, thick bedded with limonitic weathered surface. Swirl features on upper bedding plane.
3/1	1.75	18.73	Alternate thinly laminated shale and very thin to thin bedded sandstone, very fine to fine grained, medium bluish gray. 60% Shale. Thin sandstone beds at the top wedge out in a distance of few meters.
			FAULT
3/2	2.50	21.23	Alternate thinly laminated shale and very thin bedded very fine grained sandstone, medium bluish gray. 60% Shale.
3/3	0.80	22.03	Shale, medium bluish gray, thinly laminated, friable.
3/4	0.80	22.83	Alternate laminated shale and very thin bedded, very fine grained shaly sandstone, medium bluish gray.
2*	3.50	26.33	Alternate laminated shale and very thin to thin bedded very fine grained sandstone. Shale is medium bluish gray, sandstone beds are light brownish gray. 60% Shale.
1/1	1.20	27.53	Alternate thinly laminated shale and very thin bedded very fine grained sandstone, medium fluish gray. 70% Shale
			FAULT

Unit	Thickness In Meters	Cumulative Thickness	Description
1/2	25.00	52.53	Alternate laminated shale and laminated to thin bedded very fine grained sandstone, evenly bedded and dominant at the bottom of unit. 70% Shale. Drag folding and faulting distorted. Some sandstone beds are current laminated.
			COVERED?
			WHITE OAK MOUNTAIN FAULT

PINE RIDGE - OAK RIDGE SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			Pumpkin Valley Shale.
			COVERED?
80	1.32	1.32	Quartzitic sandstone, greenish gray, very fine grained, thin to medium bedded. Weathers to a grayish color.
	9.15	10.47	COVERED
79	0.66	11.13	Sandstone, light greenish gray, fine grained, medium bedded at the bottom with laminated to very thin bedded at the top.
	1.50	12.63	COVERED
78*	4.60	17.23	Sandstone, pale brown, very fine grained, very thin bedded at the bottom becoming medium bedded at the top with laminated dark greenish gray shale at the bottom. Sandstone beds have a limonitic surface.
77	0.50	17.73	Shale, dark greenish gray, thinly laminated. Flakey and friable.
76	1.50	19.23	Sandstone, grayish red, very fine to medium grained, medium bedded. Sandstone beds with limonitic surface.
75	2.50	21.73	Sandstone, dark greenish gray, very fine to medium grained, very thin evenly bedded with laminated shale.
74	2.80	24.53	Shale, dark greenish gray, thinly laminated with occasional very thin sandstone beds. Shale is grayish red at the bottom.
73	3.50	28.03	Shale, grayish red, laminated at the bottom, with silty shale at the top both interbedded with very thin to thin bedded, dark yellowish orange, very fine grained sandstone.

Unit	Thickness In Meters	Cumulative Thickness	Description
72*	1.77	29.80	Sandstone, grayish red to dark greenish gray, very fine grained, very thin to laminated. Occasional very thin quartzitic sandstone beds.
71	1.78	31.58	Quartzitic sandstone, greenish gray to grayish, fine grained with shaly coarse to very coarse grained sandstone near the top, thin to very thin bedded with occasional laminated beds. Ripple marked, current laminated. Holes on bedding plane 1 cm. in diameter. Limonitic weathered surface.
70	1.22	32.80	Sandstone, grayish red, fine to medium grained, laminated. Transported burrow casts, broken and abundant at the top.
69	0.96	33.76	Quartzitic sandstone, light gray, fine grained, thin to very thin bedded with intervening dark greenish gray laminated shale. Ripple marked. Limonitic weathered surface.
68	0.35	34.11	Shale, dark greenish gray, thinly laminated. Flakey and friable.
67*	1.00	35.11	Quartzitic sandstone, light gray, very fine grained, very thin to thin bedded with 13 cm. thick horizon of dark greenish gray laminated shale in the middle. Planolites on bedding plane. Limonitic weathered surface.
66	0.30	35.41	Shale, dark greenish gray, thinly laminated, silty.
65	1.16	36.57	Quartzitic sandstone, greenish gray, very fine grained, very thin to thin bedded. Ripple marked. Fractured and jointed.

Unit	Thickness In Meters	Cumulative Thickness	Description
64	2.80	39.37	Silty shale, grayish red, laminated interbedded with very fine grained, very thin bedded sandstone at the bottom and thin bedded sandstone at the top. Occasional lenses of coarse grained sandstone. Planolites on lower bedding plane of some beds. Current laminated with glauconitic laminae, in sandstone.
63	1.60	40.97	Quartzitic sandstone, greenish gray to light gray, very fine grained, very thin to thin bedded with intervening laminated shaly sandstone. Current laminated with glauconitic laminae. Bioturbated sandstone bed near bottom. Limonitic weathered surface.
62*	3.25	44.22	Shaly sandstone, greenish gray very fine grained, laminated with occasional very thin to thin bedded, grayish quartzitic sandstone. Occasional lenses of very coarse grained sandstone 3 cm. thick. Two horizons are bioturbated and full of burrow casts in the middle 25 cm. and at the top 50 cm.
61	0.86	45.08	Quartzitic sandstone, greenish gray, very fine grained, very thin to thin bedded with a grayish red, coarse grained 8 cm. thick sandstone bed in the middle. <u>Skolithos</u> in very thin beds. <u>Planolites</u> on lower bedding plane. Glauconite is abundant. Dark grayish red weathered surface.
60	1.70	46.78	Quartzitic sandstone, light gray, very fine grained, very thin bedded alternating with greenish gray, laminated shale. <u>Planolites</u> on lower bedding plane of some beds.
59	2.30	49.08	Shaly sandstone, dark greenish gray, very fine grained, laminated with occasional laminated grayish red shale and light gray, very thin bedded quartzitic sandstone. Occasional glauconitic sandstone, very thin bedded and medium grained. Planolites on upper bedding plane of some beds. Sandstone beds with limonitic weathered surface.

Unit	Thickness In Meters	Cumulative Thickness	Description
58	0.13	49.21	Sandstone, light green, medium to coarse grained, thin bed. Cross-bedded with alternate sandstone and glauconite laminae. Unit is a lens shaped channel.
57*	1.93	51.14	Sandstone, grayish red, fine to medium grained, very thin bedded with shaly bedding planes. Medium grained sandstone found in dark greenish gray glauconitic very thin bands. Current laminated.
56*	0.50	51.64	Dolomitic oolites, grayish red to grayish green, fine to medium size ooides at the top and coarse to very coarse size ooids at the bottom. Glauconitic medium grained, very thin bedded sandstone below the oolites. Cross-bedded. Oolites are partly hemattic. Current laminated glauconitic sandstone. Glauconite is abundant in oolites. Similar to RP Unit 126.
			FAULT
55*	6.00	57.64	Sandstone, grayish orange to greenish gray, fine grained, thin to very thin bedded, alternating with laminated greenish gray and grayish red shale and greenish gray silty shale. Current laminated sandstone. Glauconite is concentrated in dark greenish gray, very thin sandstone beds. Unit is inaccessible at the top.
54	0.71	58.35	Glauconitic sandstone, dark greenish gray, fine to medium grained, thin to medium bedded with grayish red shaly bedding planes. Current laminated with alternate sandstone and glauconite laminae.
53	0.70	59.05	Quartzitic sandstone, grayish red, very fine grained, very thin bedded alternating with laminated shale. 30% Shale. Fault perpendicular to strike. Sandstone has a limonitic color.
52	1.52	60.57	Silty shale, dusky yellow, laminated. Dark green weathered surface.

Unit	Thickness In Meters	Cumulative Thickness	Description
51	1.42	61.99	Sandstone, dusky yellow, very fine grained, very thin to thin bedded alternating with laminated light gray shale. Some beds weather to a limonitic color. Fractured and jointed sandstone.
50*	2.08	64.07	Sandstone, dusky yellow, very fine grained, very thin bedded at the bottom becoming laminated at the top. Current laminated.
49	2.03	66.10	Shaly siltstone, dusky yellow to pale brown, laminated to very thin bedded with several very thin to thin bedded, very fine grained sandstone beds in the middle. Some siltstone beds have greenish gray bedding planes. Sandstone beds are current laminated with glauconitic laminae. Jointed. Siltstone weathers easily.
	3.00	69.10	COVERED
48*	0.91	70.01	Siltstone, calcareous, dusky yellow, laminated to very thin bedded with very thin bedded, light gray limestone. Organic structures on some bedding planes.
47	0.38	70.39	Siltstone, dusky yellow, laminated. Weathers easily.
	2.50	72.89	COVERED
46	0.13	73.02	Shale, sandy, laminated greenish gray at the bottom and grayish red at the top. Looks flasered.
45	0.30	73.32	Sandstone, dark yellowish orange to pale brown, very fine grained, laminated to very thin bedded. Flasered bands at the top.
44	0.63	73.95	Silty shale, laminated, with 8 cm. horizon of greenish gray silty shale at the bottom and grayish red on top. Flaser bedding.
43	0.55	74.50	Shaly sandstone, light brownish, very fine grained, laminated with grayish red shaly bedding planes.

Unit	Thickness In Meters	Cumulative Thickness	Description
42	0.35	74.85	Sandstone, pale yellowish brown, very fine grained, laminated to very thin evenly bedded. Limonitic weathering. Fractured.
41	0.55	75.40	Silty shale, grayish red, laminated with a very fine grained, very thin sandstone bed close to bottom.
40	1.22	76.62	Sandstone, pale yellowish brown, very fine grained, thin to very thin bedded with intervening laminated, grayish red shale. 10% Shale.
39	0.91	97.53	Sandstone, grayish red, very fine grained, very thin bedded alternating with laminated shale. 40% Shale. Flaser bedding.
38*	0.55	78.08	Sandstone, pale yellowish brown, very fine grained, laminated thin unevenly bedded.
37	0.91	78.99	Shaly siltstone, dusky yellow, laminated to very thin bedded with very fine, very thin sandstone bands in the middle.
36	0.20	79.19	Sandstone, pale yellowish brown, very fine grained, very thin to thin evenly bedded. Current laminated. Jointed.
35	1.00	80.19	Silty shale and shaly siltstone, dusky yellow, laminated to very thin bedded. Looks like unit 71 in PR I-75 section. (Lalite casts.)
34	0.43	80.62	Sandstone, light brown, very fine grained, laminated to thin bedded. Fractured and jointed.
33	0.25	80.87	Shale, greenish gray, laminated with grayish orange laminated silty shale.
32	0.63	81.50	Shale, grayish red, laminated with intervening, very fine grained, very thin bedded sandstone at the bottom. 60% Shale.

Unit	Thickness In Meters	Cumulative Thickness	Description
	?		COVERED
			FAULT
	?		COVERED
31	1.50	83.00	Sandstone, grayish red to pale red, very fine grained, very thin to thin bedded with intervening laminated shaly sandstone. Shaly sandstone is modular. Weathered surface is dark greenish gray. Badly weathered. Fractured and jointed.
30	5.00	83.00	Sandstone, dark yellowish orange very fine grained, laminated to very thin bedded. Partly covered.
29	3.80	91.80	Shaly siltstone, greenish gray to dusky yellow, laminated with occasional very fine grained, very thin bedded sandstone and laminated greenish gray shale. Flaser bedding at the top.
28	3.35	95.15	Sandstone, grayish red to pale brown, very fine grained with occasional medium grained horizons, very thin to thin bedded at the bottom and medium bedded at the top. Current laminated. Planolites on lower bedding of some beds.
27*	1.82	96.97	Sandstone, grayish red to pale brown, silty to very fine grained, very thin to thin bedded interbedded with laminated shale. Halite crystal casts. Ripple marked. Micro cross-bedding. Flaser bedding.
26	2.28	99.25	Shale, grayish red, laminated with a 25 cm. thick horizon of grayish orange siltstone and greenish gray shale in the middle.
25*	1.88	101.13	Sandstone, pale brown to pale red, very fine grained, very thin to thin bedded with shaly bedding planes. Flaser bedding in the middle. Fractured and jointed.

Unit	Thickness In Meters	Cumulative Thickness	Description
24	2.70	103.83	Sandstone, pale brown to grayish red, very thin grained, very thin to thin bedded alternating with laminated shale and shaly sandstone. Shale sandstone are greenish gray at the top. Sandstone beds are current laminated. Flaser bedding. Jointed and fractured.
23	5.33	109.16	Sandstone, pale brown, very fine grained, very thin to medium bedded bottom and top with laminated shale and sandstone in the middle. 10% Shale. Mud cracks. Current laminated. Planolites on lower bedding planes of some beds. Dark greenish gray weathered surface.
22	1.22	110.38	Sandstone, greenish gray, very fine to medium grained with a medium bed at the bottom and very thin to thin bedded sandstone alternating with laminated shale. 10% Shale. Flaser bedding.
21	2.03	112.41	Sandstone, grayish red to pale red, very fine grained, very thin to thin bedded at the top alternating with laminated shaly sandstone in the middle.
20*	1.72	114.13	Sandstone, grayish red to pale red, very fine grained, very thin with occasional thin beds alternating with laminated shale and shaly sandstone in the middle. 5% Shale. Jointed and fractured.
19	1.42	115.55	Sandstone, grayish red, very fine grained, very thin bedded alternating with laminated shale. Some thin beds at the top. 20% Shale. Flaser bedding at the bottom. Dark greenish gray weathered surface.
			FAULT
18	1.50	117.50	Sandstone, pale red, very fine grained, shaly and laminated at the bottom to medium bedded at the top. Dark greenish gray weathered surface.

Unit	Thickness In Meters	Cumulative Thickness	Description
17	1.50	118.55	Sandstone, pale red, very fine grained, thin bedded with intervening laminated shaly sandstone. A light greenish gray 20 cm. thick horizon of coarse to very coarse grained sandstone is at the top underlain by silty shale. Greenish gray weathered surface.
16	3.55	122.10	Shale, grayish red, laminated silty. Friable.
15	1.98	124.08	Sandstone, grayish red, very fine grained, very thin bedded alternating with laminated to very thin beds. Fractured and jointed. Dark greenish gray weathered surface.
14	8.10	132.18	Shale, grayish red, laminated occasionally silty with very fine grained, very thin bedded sandstone 1 - 5 cm. thick close to the top. 80% Shale. Friable, partly covered.
			FAULT
13	1.10	133.28	Shale, alternate laminated greenish gray and grayish red shale at the bottom becoming grayish red at the top with occasional very thin siltstone beds.
12	2.80	136.08	Sandstone, pale brown, laminated with occasional very thin and thin beds with 10 cm. thick horizon of laminated grayish red shale in the middle. Grayish red shaly bedding planes. Sandstone has a greenish tinge.
11	2.43	138.51	Sandstone, grayish red, very fine grained, laminated with laminated shale. 35 % Shale. Flaser bedding at the top. Current laminated sandstone.
10	1.00	139.51	Shaly siltstone, grayish and, laminated. Current laminated.
9	2.28	141.79	Sandstone, grayish orange, very fine grained, very thin bedded at the bottom becoming laminated at the top. A greenish gray laminated shale 1 horizon cm. thick is at the bottom.

Unit	Thickness In Meters	Cumulative Thickness	Description
8	10.00	151.79	Sandstone, grayish red, silty to very fine grained, very thin bedded alternating with laminated shale. Sandstone more abundant at the top. 30% Shale. Flaser bedding. Current laminated. Sandstone beds in the middle have a dark greenish tinge.
7	0.55	152.34	Silty shale, grayish red, laminated.
6	1.32	153.66	Alternate very thin bedded siltstone and laminated shale, grayish red. Unit becomes more silty at the top.
5	1.52	155.18	Shaly siltstone, greenish gray laminated. Brea easily into chips.
4	1.55	156.73	Silty sandstone, pale red to moderate red, very fine grained, laminated to very thin bedded. Grayish orange surface. Fractured and jointed. Partly covered.
3	0.38	157.11	Silty shale, greenish gray, laminated. Breaks easily into chips.
2	1.42	158.53	Sandstone, silty, grayish red, very fine grained, laminated to very thin bedded. Current laminated. Looks flasered.
1	2.03	160.56	Shaly siltstone, greenish gray at the bottom becoming pale yellowish orange at the top, laminated with occasional very thin siltstone beds. Deeply weathered.
	?		COVERED Mostly grayish red shale. WHITE OAK MOUNTAIN FAULT

PINE RIDGE - YOUNG CREEK SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			Pumpkin Valley Shale
38*	5.00	5.00	Alternate thin to very thin bedded sandstone and laminated shaly to silty sandstone, greenish gray and light greenish gray, with limonitic surfaces; occasional quartzitic sandstone beds. Conglomeritic hematite pellets in several horizons in very fine to medium grained sandstone beds. Ripple marks in some beds; current laminations; rusophycus found close to the middle of unit; skolithos in a quartzitic sandstone bed. Planolites 2 - 3 mm. wide on bedding planes of some beds.
37	1.35	6.35	Quartzitic sandstone, dusky yellow to grayish orange, fine to medium grained, thin to medium bedded. Jointed, fractured and massive.
36	0.55	6.90	Shaly siltstone, light greenish gray, laminated. Friable and flakey.
35	1.90	8.80	Quartzitic sandstone, dirty greenish gray, fine grained, thin to medium bedded; limonitic blotches on surface. Jointed, fractured and massive.
	6.00	14.80	COVERED
34	1.00	15.80	Sandstone, greenish gray, very fine to fine grained, thin to medium bedded. Current laminated; jointed.
	1.70	17.50	COVERED
33*	2.70	20.20	Alternate very thin bedded sandstone and laminated shale, grayish red, very fine to fine grained sandstone. Ripple marked; Flaser bedding. Planolites on some beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
32	2.00	22.20	Sandstone, light greenish gray, very fine to fine grained, very thin to laminated at the bottom alternating with shaly to silty sandstone, becoming thin bedded in the middle and then very thin bedded at the top. Current laminations. Ripple marked, parts of unit look flasered. Planolites 2 - 3 mm. wide in some beds. Jointed.
31	1.80	24.00	Alternate very thin bedded to laminated sandstone and shale, grayish red, very fine to fine grained. Shale more abundant upward in the unit. 30% Shale Laminated shale and sandstone are flasered. Ripple marks in sandstone beds, current laminated.
30*	5.00	29.00	Alternate sandstone and and silty to shaly sandstone, light greenish gray, very fine to fine grained, laminated to thin, but mostly very thin bedded. Limonitic and dark greenish gray to pale brown weathered surface. 10% Shale. Skolithos in a thin sandstone bed. Planolites on lower bedding plane of some beds. Rectangular jointing.
29	3.12	32.12	Shale, greenish gray top 25 cm. and bottom of unit, grayish red shale alternating with laminated shaly sandstone and dark greenish gray glauconitic sandstone in the middle. 80% Shale.
28	1.98	34.10	Sandstone, greenish gray to grayish, fine grained with a coarse grained horizon 15 cm. thick; laminated to thin bedded alternating with shaly sandstone at the bottom. Sandstone weathers to a dark greenish gray color with limonitic blotches. Ripple marked. Planolites on bedding plane of some beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
27*	1.50	35.60	Sandstone, light greenish gray, very fine to coarse grained, laminated to thin but mostly very thin bedded, alternating with silty sandstone at the bottom; pale brown weathered surface at the top. Sandstone beds in the middle are friable; jointed.
26/1	2.02	37.62	Sandstone, pale red with limonitic surfaces and greenish gray bedding planes, fine to medium grained, very thin to laminated bottom, medium bedded at the top. Ripple marked; jointed.
26/2	2.15	39.77	Sandstone, grayish red, very fine to fine grained, laminated with shale at the bottom while becoming thin to medium bedded at the top. Some beds wedge out. 5% Shale bottom of unit. A very shallow channel 20 cm. deep and about 2 meters wide is filled with laminated shale and sandstone. Ripple marked. Planolites on lower bedding plane of some beds.
25	0.50	40.27	Sandstone, silty, greenish gray at the bottom and grayish red at the top of unit, fine grained and laminated. Bedding planes are not clear.
24	0.88	41.15	Sandstone, grayish red, very fine to fine grained, laminated to thin but mostly very thin bedded, sandstone has shaly bedding planes and alternates with shale in the middle of unit. 10% Shale in the middle of unit. Ripple marked; flasered in the middle. Modular bedding plane at the top. Planolites 3 mm. wide, sinuous on lower bedding planes of some beds.
23	0.38	41.53	Silty sandstone, greenish gray bottom half and grayish red upper half, fine with coarse grained sandstone lenses about 2 cm. thick, matrix is mostly medium grained, beds are laminated.
22	1.25	42.78	Sandstone, greenish gray, becoming grayish red and greenish gray towards the top, fine to coarse grained, very thin to thin bedded; coarse grained conglomeritic sandstone bed 25 cm. thick at the top.

Unit	Thickness In Meters	Cumulative Thickness	Description
22*	1.25	42.78	Sandstone, greenish gray, becoming grayish red and greenish gray towards the top, fine to coarse grained, very thin to thin bedded; coarse grained conglomeritic sandstone, bed 25 cm. thick at the top. Current laminated; ripple marks on top bed of unit. Transported burrow casts alternate with sandstone beds and become dominant at the top.
21	0.75	43.53	Sandstone, grayish red at bottom to greenish gray at the top, fine to very coarse grained, no apparent bedding, looks massive. Cross bedded. Transported burrow casts with lenses of pebbly hemotite pellets. Sandstone beds are current laminated.
20	1.58	45.11	Sandstone, grayish red, medium grained very thin to thin bedded at the bottom with greenish gray laminated shaly sandstone middle and quartzitic sandstone pale yellowish brown, very fine grained very thin to thin bedded at the top with a limonitic surface. Current laminations in some beds. _Planolites_ in grayish red sandstone and laminated shaly sandstone.
19	1.15	46.26	Quartzitic sandstone, pale yellowish brown to grayish, very fine to fine grained, very thin to thin bedded, with limonitic surfaces. Some beds are ripple marked; jointed and fractured.
18	1.55	49.81	Silty sandstone, grayish red very fine to fine grained, looks massive, with greenish gray shaly sandstone, then grayish red silty sandstone and greenish gray shaly sandstone, very thin to laminated. Coarse grained greenish gray sandstone bed 12 cm. at the top. Planolites on upper bedding plane of sandstone at bottom. Greenish gray shaly sandstone is bioturbated.

Unit	Thickness In Meters	Cumulative Thickness	Description
17	0.77	48.58	Quartzitic sandstone, greenish gray at bottom and grayish red at the top, very fine to coarse grained, laminated to thin but mostly very thin bedded. Two horizons of very thin coarse grained sandstone in the middle. One bed has a modular bedding plane. Skolithos in a very thin bed at the bottom. Current laminations in some beds.
16*	6.15	54.73	Alternate very thin sandstone and laminated silty to shaly sandstone, greenish gray, mostly very fine to fine grained, occasional medium grained sandstone, a grayish red to greenish black very coarse sandstone bed is at the top of unit. Skolithos in some sandstone beds at the top. Ripple marked. Planolites on some beds. Silty sandstone beds look massive and are bioturbated. Glauconitic laminations in some sandstone beds.
15	3.25	57.98	Alternate very thin sandstone and laminated shale, grayish red with occasional very thin medium grained glauconitic sandstone. Sandstone mostly fine grained. 20% Shale. Some sandstone beds are lenses which thicken and thin.
14	0.60	58.58	Shale, grayish red, thinly laminated. Flakey and friable.
13	2.50	61.08	Alternate sandstone and shaly sandstone, laminated to very thin bedded, pale brown to greenish gray, fine grained. Sandstone is slightly glauconitic. Planolites 2 - 3 mm. wide are abundant in some beds.
12*	2.00	63.08	Alternate shaly glauconitic sandstone and shale, grayish red, very fine to fine grained, laminated bottom 38 cm.; unit becomes medium gray, thin bedded sandstone with occasional dolomitic beds, with 3 cm. of oolites at the top of unit. Oolites top of unit. Sandstone beds are current laminated; in some beds the laminations are glauconitic. Jointed.

Unit	Thickness In Meters	Cumulative Thickness	Description
11	3.80	66.88	Shaly stilstone, medium blue gray, laminated alternating with very fine grained very thin evenly bedded sandstone; shaly siltstone becomes dominant towards the top and dolomitic. Shaly siltstone 80%. Some sandstone beds are ripple marked and current laminated.
10*	4.15	71.03	Limestone, medium gray, very fine grained, thin to medium bedded at the bottom with very thin to laminated in the middle and medium bedded at the top; very fine grained sandstone stringers in limestone. Intricate intraclasts in two horizons 3 - 5 cm. thick, bottom and middle of unit; current laminations. Planolites on bedding plane of some beds at the bottom. Similar to PR 118/3.
9	3.83	74.86	Silty shale, grayish orange, laminated, with a 30 cm. thick laminated calcareous siltstone bed at the bottom. Alternate grayish red shale and shaly sandstone very thin to laminated in the middle and greenish gray shale at the top. 75% Shale. Phycodes 2.5 cm. wide on a grayish red bed in the middle.
8	3.55	78.41	Alternate sandstone and shale, very thin to laminated, grayish red, very fine to fine grained with thin bedded sandstone above the middle. 10% Shale. Ripple marked; flaser bedding, bottom of unit. Planolites 1.5 cm. wide are abundant on lower bedding plane of some beds.
7	2.65	81.06	Quartzitic sandstone, medium bluish gray bottom 15 cm. becoming greenish gray and light brownish gray at the top, fine grained, very thin bedded at the bottom becoming thin bedded at the top. Ripple marks; glauconitic laminations in some beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
6	1.20	82.26	Quartzitic sandstone, light gray, very fine to fine grained, very thin to medium bedded. Ripple marks; current laminations in some beds. Skolithos 2 - 3 mm. wide, 1.5 cm. long.
5	2.68	84.94	Calcareous siltstone and shale, dark greenish gray, very thin to laminated with fine grained thin bedded grayish dolomitic sandstone in the middle, the calcareous siltstone becomes grayish orange in color at the top. Calcareous siltstone 40%. Ripple marks. Planolites 1.5 cm. wide in the shales.
4*	0.85	85.79	Quartzitic sandstone, light gray to greenish gray, fine grained, very thin bedded with occasional thin beds. Top bed is ripple marked. Planolites on upper bedding palnes of some beds.
3	1.50	87.29	Sandstone, grayish red, fine grained, laminated to thin bedded at the bottom with silty bedding planes. Unit is medium bedded with conglomeritic very coarse sandstone at the top 45 cm. with greenish gray color top 12 cm. Jointed.
2*	4.08	91.37	Sandstone, grayish red, very fine to fine grained, thin bedded at the bottom and close to the top with shaly bedding planes; laminated dusky yellow silty sandstone 25 cm. thick in the middle. Ripple marked. Cruziana; Planolites 1.5 cm. wide on lower bedding plane of some beds.
1	1.50	92.87	Sandstone, grayish red, very fine to fine grained, laminated to very thin bedded, with shaly to silty bedding planes. Current laminations in some beds. Planolites and worm tracks on some beds.
			COVERED?
			WHITE OAK MOUNTAIN FAULT

BULLRUN RIDGE - DIGGS GAP SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			PUMPKIN VALLEY SHALE
40/1*	0.20	0.20	Quartzitic sandstone, whitish to greenish, coarse grained, thin to medium bedded. Fractured.
40/2	1.05	1.25	Alternate very thin bedded sandstone and laminated silty shale, dusky yellow, very fine to fine grained. 20% Shale. Flaser bedding.
40/3*	1.90	3.15	Sandstone, pale yellowish brown very fine to fine grained, very thin to thin bedded; flasered sandstone and shale in the middle of subunit; greenish gray shaly bedding planes. 5% Shale. Some beds are current laminated. Flaser bedding.
40/4	0.20	3.35	Alternate laminated shale and sandstone, very fine to fine grained, pale olive. Flasered.
40/5	1.00	4.35	Silty sandstone, pale brown to grayish red, very fine to fine grained, very thin to thin bedded.
40/6	1.65	6.00	Sandstone, pale yellowish brown, very fine to fine grained, very thin to thin bedded.
40/7	1.50	7.50	Sandstone, dark greenish gray with a pale yellowish brown surface, very fine to fine grained, thin to medium bedded. Sandstone looks massive, fractured and jointed.
40/8*	2.75	10.25	Sandstone, silty, greenish gray, very fine grained, medium to thick bedded. Unit badly weathered with limonitic colored surfaces; fractured.
			FAULT

Unit	Thickness In Meters	Cumulative Thickness	Description
39/1	8.00	18.25	Shale, light olive gray to pale brown, thinly laminated with occasional very thin bedded, very fine to fine grained sandstone. 65% Shale. Ripple marked.
39/2	2.25	10.50	Alternate laminated shale and very fine grained sandstone dusky yellow to pale yellowish brown. 50% Shale. Flasered
39/3	1.75	22.25	Shale, dusky yellow to dark greenish gray, laminated with occasional very thin bedded fine grained sandstone with a 25 cm. thick wedge of quartzitic sandstone at the top with glauconitic sandstone below the wedge. 50 - 60% Shale.
38/1*	1.50	23.75	Sandstone, pale brown, very fine to fine grained, laminated to thin bedded. Fractured.
38/2	0.25	24.00	Alternate laminated shale and sandstone very fine to fine grained. 10 - 20% Shale. Flasered.
38/3	2.25	26.25	Quartzitic sandstone, grayish red, very fine to fine grained, thin to medium bedded. Fractured and jointed.
38/4	1.75	28.00	Quartzitic sandstone, greenish gray to pale yellowish brown, very fine to fine grained, thin bedded with occasional very thin dark greenish gray beds.
37	1.05	29.05	Quartzitic sandstone, dark yellowish orange, very fine to fine grained, very thin to thin bedded. Fractured.
36	2.18	31.23	Quartzitic sandstone, whitish to pale yellowish brown with grayish blotches, very fine to fine grained, thin to medium bedded. Pale yellowish brown internal laminations. Fractured and shattered.

Unit	Thickness In Meters	Cumulative Thickness	Description
35/1	2.40	33.63	Silty sandstone, light greenish gray, very fine grained, laminated. Drag folds due to faulting.
35/2	2.15	35.78	Alternate, very thin bedded sandstone and thinly laminated shale, grayish red to dark brown, sandstone is very fine to fine grained with occasional coarse grained glauconitic sandstone.
35/3	1.10	36.88	Shale, grayish red to pale brown thinly laminated, with occasional very thin bedded siltstone and occasional greenish gray shale bands. 85% Shale.
35/4	0.80	37.68	Shale, greenish gray, thinly laminated. Flakey and friable.
34	2.45	40.13	Sandstone, pale brown, very fine to fine grained, thin to very thin evenly bedded with laminated greenish gray silty shale.
33	1.80	41.93	Quartzitic sandstone, greenish gray with a rusty surface, very fine to fine grained, very thin to medium bedded; some beds are glauconitic and medium gray in color. Fractured and shattered.
			FAULT
32*	2.45	44.38	Quartzitic sandstone, pale yellowish brown to pale brown, very fine to fine grained, medium bedded at the bottom becoming evenly thin bedded at the top. Dark greenish gray laminations in beds at the top.
31/1	1.35	45.73	Alternate grayish red, laminated shale and pale brown very fine grained, very thin to thin bedded sandstone, with greenish gray shaly bedding planes. 25 cm. of greenish gray shale at the bottom. 65% Shale
31/2	0.30	46.03	Shale and shaly sandstone, greenish gray, very fine grained, thinly laminated to laminated. 60% Shale. Ripple marks.

Unit	Thickness In Meters	Cumulative Thickness	Description
31/3	0.33	46.36	Shale and shaly sandstone, greenish gray, very fine grained, thinly laminated to laminated. 60% Shale. Ripple marks.
30*	1.80	48.16	Quartzitic sandstone, whitish to light bluish gray, very fine to medium grained, thin bedded with some very thin and medium beds; shaly bedding planes; pale yellowish orange top and bottom of individual beds. Large ripple marks - light greenish gray bands in some beds.
29	0.50	48.66	Alternate pale yellowish brown very fine to fine grained sandstone very thin bedded and laminated light greenish gray shale. 20% Shale. Ripple marked; flasered.
28	0.45	49.11	Quartzitic sandstone, pale brown to pale yellowish brown, very fine to fine grained with occasional coarse grained beds; thin to medium unevenly bedded. Some beds wedge out; fractured and shattered.
27	1.30	50.41	Shaly sandstone, grayish red, very fine to fine grained, very thin bedded interbedded with dark greenish gray sandy shales. 20% Shale. Micro cross-bedding in troughs of ripple marks.
26	1.43	51.84	Quartzitic sandstone, grayish orange, very fine to fine grained, laminated to very thin bedded with 25 cm. thick bed of light greenish gray silty shales at the bottom of unit. Ripple marked. Burrow casts in silty shale.
25/1	0.75	52.59	Sandstone, grayish red, very fine to fine grained, very thin to thin bedded interbedded with laminated dark greenish gray shaly sandstone. Flaser bedding.

Unit	Thickness In Meters	Cumulative Thickness	Description
25/2	1.75	54.34	Sandstone, grayish red, very fine to fine grained, very thin to medium bedded with some laminated dark greenish gray shaly sandstone in the middle. Fractured and jointed.
25/3	0.55	54.89	Sandstone, grayish red, very fine to fine grained, very thin to thin bedded. Ripple marked; fractured and jointed.
24*	2.10	56.99	Quartzitic sandstone, greenish gray, very fine to fine grained, very thin to medium bedded, interbedded with laminated light greenish gray shaly sandstone, fine to medium grained.
23/1	1.75	58.74	Shaly to silty sandstone, light greenish gray to dusky yellow very fine grained, laminated looks modular and badly weathered with limonitic surface. Bioturbated.
23/2	2.50	61.24	Shale and shaly sandstone, pale brown, very fine to fine grained, laminated to very thin bedded with dark greenish gray glauconitic sandstone lenses. 50% Shale. Current laminated; flaser bedding at the bottom; micro cross-bedding in glauconitic sandstone. _Planolites_ in some beds.
23/2	0.25	61.49	Glauconitic sandy shale, greenish gray, very fine to fine grained, laminated.
22*	0.48	61.97	Quartzitic sandstone, dark greenish gray to dark gray very fine to fine grained, laminated to very thin bedded with fine to medium grained shaly sandstone. Fine laminations of pure sandstone and greenish black glauconite.
21	1.60	63.57	Quartzitic sandstone, grayish red to dark greenish gray, very fine to fine grained, laminated to very thin bedded, with a thin sandstone bed at the top. 10% Shale. Flasered sandstone and shale at the bottom. Ripple marked.

Unit	Thickness In Meters	Cumulative Thickness	Description
20	0.78	64.35	Sandstone, greenish gray, glauconitic, with a limonitic surface, very fine to fine grained, very thin to thin bedded, with occasional shaly sandstone. Sandstone is modular.
			FAULT
19	1.80	66.15	Sandstone shaly and silty, greenish gray to dark greenish gray with limonitic blotches, very fine to fine grained, thin bedded with occasional very thin and medium beds. Unit is full of burrow casts. Modular and badly weathered.
18	0.85	67.00	Shale, silty, grayish red, thinly laminated, flakey and friable, with very thin, very fine grained sandstone beds at the top. 50% Shale.
17*	4.50	71.50	Sandstone, grayish red, very fine grained, medium bedded with occasional very thin and thin beds, with greenish gray bedding planes. A very thin bed of dark greenish gray sandstone in the middle of unit. Some beds wedge out.
			FAULT
16*	3.00	74.50	Shale, grayish red thinly laminated, friable interbedded with, very thin bedded, dark greenish gray quartzitic sandstone. Greenish gray sandy shale 35 cm. thick at the bottom. 80% Shale. Drag folds.
15	1.60	76.10	Quartzitic sandstone, grayish red to dark greenish gray, very fine grained, very thin bedded with occasional laminated and thin beds; interbedded with hematitic laminated silty shale at the bottom. Flasered at the bottom.

Unit	Thickness In Meters	Cumulative Thickness	Description
14*	3.75	79.85	Quartzitic sandstone, greenish gray to medium gray with limonitic surfaces, very fine to fine grained, medium to very thin bedded with thin beds of siltstone and dark greenish gray fine to coarse grained glauconitic sandstone. 5% Shale. Dark greenish gray weathered surface.
13	0.70	80.55	Shale, grayish red to grayish brown, thinly laminated, flakey and friable, interbedded with very thin bedded, very fine grained quartzitic sandstone. 60% Shale.
12	4.50	85.05	Sandstone grayish red to pale brown, very fine to fine grained, medium bedded with occasional thin beds, interbedded with dark greenish, very thin bedded shale. Glauconitic laminations in beds at the top.
11*	1.50	86.55	Sandstone, grayish red, very fine grained, thin bedded, interbedded with laminated shale and sandstone. 30% Shale. Flute marks; ripple marks; tidal balls; flasered bedding in laminated shale and sandstone. Abundant <u>Rusophyous</u> and <u>Cruziana</u>.
10*	1.38	87.93	Sandstone, dusky yellow to pale olive, very fine to fine grained, thin to medium bedded with laminated greenish gray shale at the top.
9	1.83	89.76	Alternate, very thin quartzitic sandstone, very fine grained and laminated shale; greenish gray to medium light gray becoming pale brown at the top. 50% Shale.
8	0.30	90.06	Sandstone and silty shale, grayish red, thinly laminated to laminated, very fine grained.
7	0.15	90.21	Quartzitic sandstone, greenish gray, very fine grained, laminated to very thin bedded. Fractured and jointed.

Unit	Thickness In Meters	Cumulative Thickness	Description
6	1.00	91.21	Quartzitic sandstone, grayish orange, very fine to fine grained, medium to very thin bedded. Fractured and jointed.
5	3.00	94.21	Sandstone, shaly, grayish red, very fine to fine grained, very thin to medium bedded.
			FAULT
4	0.78	94.99	Glauconitic sandstone and silty shale; pale brown to grayish red, very fine to fine grained, laminated to very thin bedded. 40% Shale.
3/1*	0.30	95.29	Quartzitic sandstone, whitish to greenish gray, fine grained, very thin to thin bedded with laminated pale brown shale. 10% Shale.
3/2	0.40	95.69	Quartzitic sandstone, glauconitic, very fine grained very thin bedded dark greenish gray interbedded with laminated pale brown silty shale. 25% Shale.
3/3*	0.43	96.12	Quartzitic sandstone, whitish to greenish gray, fine to medium grained, thin bedded.
2	1.60	97.72	Shale, grayish red to pale brown, thinly laminated with greenish gray shale at the bottom; occasional very thin glauconitic sandstone very fine to fine grained. 65% Shale.
1/1*	6.25	103.97	Sandy dolomite, medium gray, very fine grained medium to thin bedded with occasional laminated shale. Fractured and jointed; bedding is distorted. Grayish orange weathered surface.
1/2*	2.75	106.72	Sandstone, dolomitic, medium gray, very fine grained, very thin to thin bedded with laminated shale at the bottom; sandstone increasing towards the top. Some sandstone beds are pale brown to grayish red. 40 - 50% Shale. Folded and faulted.

Unit	Thickness In Meters	Cumulative Thickness	Description
1/2	2.75	106.72	Sandstone dolomitic, medium gray, very fine grained, very thin to thin bedded with laminated shale at the bottom; sandstone increasing towards the top. Some sandstone beds are pale brown to grayish red. 40 - 50% Shale.
			COPPER CREEK FAULT

BULLRUN RIDGE - NELSON BRANCH SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			Alternate sandstone and shale very thin to laminated, dark greenish gray with limonitic surfaces. Base of Pumpkin Valley.
26	2.40	2.40	Shaly to silty laminated pale yellowish brown sandstone alternating with thin to very thin, very fine to fine grained sandstone. Not very well exposed.
25	0.50	2.90	Sandstone, moderate orange pink, fine grained, medium bedded. Jointed.
24	2.80	5.70	Alternate grayish orange thin to very thin bedded, fine sandstone and light greenish gray shaly to silty laminated sandstone. Some sandstone beds are modular.
23	3.50	9.20	Sandstone, grayish orange, fine to very fine grained, thick to thin bedded. Some beds are porous and vesicular, Planolites on bedding planes of some beds. Faulted and jointed.
22*	1.15	10.35	Dolomite, medium gray, thick bedded, with a rough surface due to the presence of intraclasts. Weathers to blackish brown.
21	2.10	12.45	Quartzitic sandstone, light gray, very fine to fine grained, medium to thin bedded; internal laminations are faint. Jointed; Planolites on lower bedding plane of some beds, 1 cm. wide and tapering in one direction.
20	1.50	13.95	Sandstone, greenish gray, very fine to fine grained, very thin to medium bedded, fine internal laminations; unit becomes very thin bedded with alternate sandstone and shale at the top. Weathers to a dark brownish color; not very well exposed.

Unit	Thickness In Meters	Cumulative Thickness	Description
19*	1.25	15.20	Shale, greenish gray, thinly laminated at bottom, with grayish red shaly very fine grained, laminated and very thin bedded sandstone 35 cm.; unit becomes more sandy at top with bluish gray shaly bedding planes on sandstone beds. 40% Shale. Cruziana, Rusophycus and Planolites in some beds at the top.
18	0.50	15.70	Dolomite, sandy, medium grey, very fine to fine grained, unit is thin bedded at the top; alternate very thin and laminated sandstone and shale bottom 15 cm. Pale yellowish brown weathered surface.
17*	0.63	16.33	Quartzitic sandstone, light grayish, very fine to fine grained, thin to medium bedded; unit looks massive. Rusophycus and Planolites on lower bedding plane of some beds.
16*	1.20	17.53	Dolomite, sandy, medium gray laminated to thin bedded, with intervening, shale, sandstone and flasered shale and sandstone; a 10 cm. band of bioturbated sandstone with black shale is congricuous. (Similar band in Pump House Road Section.) 15% Shale. Dolomite bed above bioturbated sandstone is ripple marked.
15	0.50	18.03	Quartzitic sandstone, white to light gray, very fine to fine grained, thin bedded fine internal laminations. Jointed and looks sugary.
14*	2.55	20.58	Alternate quartzitic sandstone and shale, grayish red to purplish, laminated to thin bedded, sandstone very fine to fine grained, some beds are flasered. 25% Shale. Mud cracks at the bottom of unit, ripple marked, straight Planolites 3 mm. wide and 2 - 5 cm. long lower bedding plane of some beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
13*	4.00	24.58	Quartzitic sandstone, pale yellowish brown to light brownish to purplish, very fine to fine grained, very thin to thick bedded but mostly thin. Jointed, looks massive. Scoyenia - 2 cm long at the top and middle of unit filled with silt and mud could be seen in outcrop due to darker color; Skolithos at bottom are trumpet shaped and empty. 125 cm. from bottom Cruziana and Rusphycus are found in thin quartzitic sandstone; planolites ½ cm. wide and 5 cm. long on lower bedding planes of some beds.
12	3.80	28.38	Shale, grayish red at bottom and greenish gray at the top is thinly laminated, with occasional very thin sandstone beds, dark greenish gray glauconite is abundant at the bottom of the unit in medium grained laminated sandstone beds. 60% Shale. Planlites 2 - 3 mm. wide and 5 cm. long on lower bedding of some sandstone beds.
11	1.15	29.53	Quartzitic sandstone, light grayish, very fine to fine grained, thick bedded. Looks massive.
10*	2.25	31.78	Quartzitic sandstone, light brownish to dirty greenish gray with some grayish red beds, very fine to fine grained, very thin to thin bedded mostly the latter; occasional thin laminated grayish red shales. 5% Shale. Two to three horizons of very thin and thin sandstone full of Cruziana and Rusophycus in one horizon they are associated with mud cracks and in another with ripple marks; Planolites on lower bedding planes of some beds; unit is faulted and jointed.
	3.15	34.93	COVERED

Unit	Thickness In Meters	Cumulative Thickness	Description
9	0.60	35.53	Sandstone, grayish red, very fine to fine grained, shaly at the bottom, becoming silty and very thin bedded at the top. Ripple marked; planolites 1 mm. wide 1 - 2 cm. long on lower and upper bedding planes; top of unit partly eroded.
8	0.58	36.11	Quartzitic sandstone, grayish pink to light greenish gray, very fine to coarse grained, medium bedded at the bottom and very thin bedded and coarse grained at the top. Unit looks modular and massive.
7*	2.10	38.21	Shale, greenish gray, thinly laminated, interbedded with very thin evenly bedded very fine grained sandstone which has a limonitic hematitic surface; sandstone is light greenish gray with glauconite in some medium grained bands. Large phycodes up to 3 cm. long, look like <u>Harlania</u> or <u>Arthrophycus</u>. Some planolites are 1.7 cm. wide and more than 15 cm. long.
6	1.65	39.86	Quartzitic sandstone, light brownish to light greenish gray, very fine grained, very thin to medium bedded; flasered very thin, and laminated sandstone and shale 20 cm., greenish gray bedding planes in sandstone beds. Ripple marked, <u>Rusophycus</u> in a very thin sandstone bed close to the top.
5*	0.95	40.81	Sandstone, grayish red, fine grained, thin to medium bedded, unit looks massive at the bottom. <u>Planolites</u> abundant on greenish gray bedding plane.
4	1.95	42.76	Shaly sandstone laminated interbedded with very thin bedded sandstone, grayish red, very fine to fine grained with occasional medium to coarse grained glauconitic sandstone bands. Shaly sandstone is bioturbated; fine <u>Planolites</u> on upper bedding plane of some beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
3	1.88	44.64	Shaly sandstone, greenish gray, laminated, with occasional very thin bedded light brownish fine sandstone beds, shaly sandstone looks massive. Shaly sandstone is bioturbated, some sandstone beds have hematitic surfaces, fractured and jointed.
2	1.15	45.79	Sandstone, greenish gray to light brownish, very fine to fine grained, very thin bedded, interbedded with shaly sandstone; glauconitic laminations in sandstone beds. *Planolites* 1 cm. wide on lower bedding plane of some beds. Ripple marked.
1	3.75	49.57	Sandstone, light brownish, very fine to fine grained, very thin bedded alternating with laminated greenish gray shaly sandstone, glauconite is found in fine to medium grained sandstone bands, sandstone beds have a grayish orange surface; some beds look flasered. *Planolites* mostly 2 mm. wide and different lengths are found on upper and lower bedding planes. Ripple marks in sandstone beds.
			COPPER CREEK FAULT

BULLRUN RIDGE - PUMPHOUSE ROAD SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			PUMPKIN VALLEY SHALE
26*	6.00	6.00	Sandstone, pale yellowish brown, very fine to fine grained, laminated with greenish gray shale at the bottom, sandstone is thin to medium evenly bedded at the top. 10% Shale. Flaser bedding bottom of unit; ripple marks in sandstone beds at bottom. Planolites ½ cm. wide sinuous; mud cracks.
25	3.88	9.88	Sandstone, pale yellowish brown to grayish with dark purple mottled surfaces, very fine grained, thin to thick bedded, but mostly medium bedded; parts of unit look massive but are thin bedded. Current laminated.
24	2.95	12.83	Quartzitic sandstone, olive gray with a grayish surface, fine grained, very thin to medium bedded; mostly very thin to thin evenly bedded. Current laminated.
23/1*	0.35	13.18	Dolomite, sandy, medium gray, with a dark yellowish brown weathered surface, very fine grained, medium bedded. Jointed; similar to unit 22 Bullrun Ridge Nelson Branch section.
23/2	0.65	13.83	Sandstone, pale yellowish brown, grayish weathered surface, fine grained, very thin to thin evenly bedded. Current laminated; jointed.
23/3	0.13	13.96	Alternate siltstone and shale, pale yellowish brown to greenish gray, laminated. Flasered.
23/4	0.48	14.44	Calcareous siltstone, pale yellowish brown, medium bedded. Current laminated at the top ; fractured and jointed, looks massive.

Unit	Thickness In Meters	Cumulative Thickness	Description
23/5	0.50	14.94	Sandstone, glauconitic, greenish gray to whitish, fine grained, thin evenly bedded. Fractured.
22*	0.90	15.84	Alternate shale and shaly siltstone, greenish gray, laminated, with a medium gray 20 cm. thick dolomite bed in the middle. Flasered. Ripple marks on dolomite bed.
21	0.60	16.44	Quartzitic sandstone, pale yellowish brown with a pale brown weathered surface, very fine to fine grained, very thin to thin bedded. Ripple marked; micro cross-bedding in some beds.
20	0.83	17.27	Siltstone, calcareous, grayish orange, deeply weathered in some places to dusky yellowish brown laminated to very thin bedded. Three laminated horizons of very fine sandstone and black shale at the bottom of unit; laminated greenish gray shale at the bottom of unit. 5% Shale Laminated horizons are burrowed, similar to unit 16 in Bullrun Ridge Nelson Branch section. Unit is faulted.
19	4.08	21.35	Sandstone, pale yellowish brown very fine to fine grained, laminated to thin bedded, occasionally quartzitic with greenish shale at the bottom and grayish red shale at the top; sandstone is evenly bedded. Ripple marks in some beds; flaser bedding clear in grayish red beds. Tight anti-cline and syncline which disappear laterally. 10% Shale.
18*	3.05	24.40	Sandstone, pale eyllowish brown, fine grained, very thin to thin bedded, alter-nating with laminated greenish gray shale at the bottom of unit; unit becomes mostly medium bedded with grayish red sandstone at the top. 5% Shale. Rusophycus in one bed; grayish red beds are current laminated; jointed.

Unit	Thickness In Meters	Cumulative Thickness	Description
17*	1.73	26.13	Sandstone, pale yellowish brown very fine to fine grained, laminated to medium bedded, but mostly very thin to thin bedded; very thin sandstone alternates with greenish gray shale at bottom; there is a medium sandstone bed at the top; shaly bedding planes. <u>Rusophycus</u> and <u>Cruziana</u>; some beds are ripple marked.
16*	4.18	30.31	Shale, grayish brown, laminated with 50 cm. of laminated greenish gray shale at the top and 88 cm. at the bottom; occasional fine grained, very thin bedded greenish black glauconitic sandstone. Shale at top is interbedded with very thin sandstone, one horizon is conglomeritic. Conglomeritic hematite pellets in sandstone horizon at the top.
15*	1.65	31.96	Sandstone, grayish red, very fine to fine grained, very thin bedded with occasional thin beds; shaly bedding planes. <u>Cruziana</u> and <u>Rusophycus</u>; ripple marked; unit distorted by folding.
			FAULT
14*	3.05	35.01	Alternate, very thin, fine grained sandstone and laminated shale, greenish gray with limonitic surfaces; occasional thin bedded sandstone and coarse grained quartz in some beds. 5% Shale. <u>Planolites</u> 1 cm. wide, curvy on lower bedding plane; jointed.
13*	2.40	37.41	Quartzitic sandstone, grayish red at the bottom to light gray and pale yellowish brown top, very fine to fine grained, medium bedded. Planolites, 1 cm. wide, criss-crossing and curvy, abundant on lower bedding plane on the bottom beds; greenish gray laminations in most beds; jointed and fractured.

Unit	Thickness In Meters	Cumulative Thickness	Description
12	1.18	38.59	Sandstone, grayish red, very fine to fine grained, laminated to medium bedded, but mostly very thin and medium bedded; shaly bedding planes; laminated sandstone and shale at the top. 5% Snale. Current laminated, flaser bedding in laminated sandstone and shale; jointed and fractured.
11	1.28	39.87	Sandstone, grayish red, very fine to fine grained, laminated to thin bedded, but mostly thin bedded; laminated alternate shale and sandstone. 5% Shale Flaser bedding in laminated shale and sandstone; jointed and fractured.
10	1.16	41.03	Sandstone, grayish red with greenish gray bedding planes, very fine to fine grained, lamianted shaly sandstone and shale top 25 cm., and thin bedded at the bottom. <u>Planolites</u>, ½ cm. to 1 cm. wide. Flaser bedding at the top of unit. Bottom of unit is brecciated.
9/1	0.50	41.53	Alternate very thin bedded sandstone and laminated shale, grayish red, sandstone very fine grained. 20% Shale.
9/2	0.25	41.78	Quartzitic sandstone, greenish gray, very fine to fine grained, very thin bedded.
9/3	0.50	42.28	Alternate very thin sandstone and laminated shale, with greenish gray and grayish red colors; sandstone is very fine grained. 35% Shale. Flaser bedding.
8	1.05	43.33	Quartzitic sandstone, pale brown with greenish gray surfaces, very fine to medium grained, laminated to medium bedded; greenish gray medium bedded medium grained quartzitic sandstone at the top; 25 cm. of laminated silty shale in the middle. Flaser bedding in laminated silty shale; jointed; greenish color is due to the presence of glauconite in medium grained sandstone.

Unit	Thickness In Meters	Cumulative Thickness	Description
7	1.73	45.06	Sandstone, grayish red with shaly bedding planes, very fine to fine grained, very thin to medium bedded; mottled greenish gray and grayish red sandstone beds with dirty grayish brown weathered surface. Ripple marked; *Planolites* and worm trails in some beds. Unit distorted by folding.
6	0.75	45.81	Sandstone, grayish orange, very fine to fine grained, very thin to medium bedded, pale yellowish brown weathered surface. Dip of beds is vertical; beds are brecciated.
			FAULT
5*	0.88	46.69	Sandstone, grayish red, fine grained with occasional coarse grained, glauconitic sandstone lenses, laminated to thin bedded. A thin bed of laminated greenish gray and grayish red shale at the top. Coarse grained glauconitic sandstone lenses are probably very shallow tidal flat gullies.
4	0.95	47.64	Quartzitic sandstone, pale yellowish brown, very fine grained, very thin to thin bedded. Glauconite is not abundant but could be seen in hand specimens.
3*	4.32	51.96	Alternate very thin sandstone and laminated sandy shale, dark yellowish orange to pale brown, fine grained with occasional very thin bedded coarse grained glauconitic sandstone lenses. 10% Shale. Tidal balls coated with grayish red shale, similar to Bullrun Ridge Diggs Gap Section Unit II.
2*	1.43	53.39	Sandy dolomite, dark gray very fine grained, medium bedded at bottom with dark yellowish brown very fine grained medium bedded sandstone on top. Dolomite weathers to dirty grayish brown.

Unit	Thickness In Meters	Cumulative Thickness	Description
1	0.50	53.89	Sandstone, dark yellowish brown, very fine grained, very thin to laminated evenly bedded, with thin silty sandstone bed at the top.
			COVERED?
			COPPER CREEK FAULT

BULLRUN RIDGE - DUG RIDGE SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			COVERED
28*	4.25	4.25	Alternate laminated shale and shaly sandstone, grayish red, very fine to fine grained at the bottom of the unit. Very thin to medium bedded sandstone at the top, mostly thin bedded and very fine grained. 5% Shale. Flasered at the bottom. Current laminations and ripple marks in some sandstone beds. Large Rusophycus. Phycodes 2 cm. wide and straight on lower bedding plane in a bed close to the top.
27*	2.50	6.75	Quartzitic sandstone, pale yellowish brown to grayish orange, very fine to fine grained, very thin to laminated at the bottom, becoming thin bedded at the top with shaly bedding planes. Planolites on lower bedding of some beds, not abundant.
26*	2.48	9.23	Sandstone, pale eyllowish brown and grayish red, very fine to fine grained medium bedded at the bottom with a coarse grained sandstone lens 1 - 2 cm. thick. Occasional very thin grayish shale horizons, grayish red silty sandstone, fine grained, thin to laminated looks massive with occasional coarse grained sandstone horizons. Bottom bed is full of sinuous Planolites 1.5 cm. wide. Planolites on lower bedding plane of grayish red silty sandstone.
25*	2.58	11.81	Quartzitic sandstone, bluish gray, fine grained, thin bedded at the bottom with laminated and very thin bedded alternate sandstone and shaly sandstone, fine grained at the top; occasional grayish red, coarse grained, very thin sandstone horizons with glauconitic laminations.

Unit	Thickness In Meters	Cumulative Thickness	Description
			Rusophycus and Cruziana. Planolites 1 cm. wide on lower bedding of some beds. Flaser bedding in laminated sandstone and shaly sandstone. Ripple marked. Unit is grayish orange.
24	1.75	13.56	Silty sandstone, greenish gray, very fine grained, laminated with limonitic surfaces. Unit looks massive.
23	2.00	15.56	Alternate quartzitic sandstone and shaly sandstone, grayish red, very fine to fine grained, thin bedded at the bottom becoming very thin and laminated at the top. A greenish gray, coarse grained sandstone bed, 10 cm. thick is at the bottom. Flaser bedding at the top. Ripple marks and current laminations in many beds. Planolites on lower bedding plane of some beds.
22	5.90	21.46	Alternate very thin bedded sandstone and laminated shale, grayish red, fine grained lower 2.50 m. 30 - 40% Shale, unit becomes shaly sandstone upward with increase in very thin evenly bedded sandstone with occasional coarse grained sandstone lenses. Flaser bedding at the bottom; glauconitic laminations in very thin sandstone beds. Planolites on lower bedding planes of some beds.
21*	2.88	24.34	Alternate very thin bedded sandstone and laminated shale, grayish red at the bottom, fine grained; sandstone becomes medium bedded close to the top with a 10 cm. thick dark greenish gray, coarse grained glauconitic sandstone bed at the top. Flaser bedding at the bottom. Some beds are current laminated. Planolites on lower bedding plane of some beds.
20	9.00	33.34	Dolomite sandy to silty, light grayish to grayish olive, very fine grained, mostly thin to medium bedded; occasional thin to very thin bedded sandstone and shaly sandstone beds; sandstone stringers and grayish red laminations in some dolomite beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
			Current laminated. Jointed and fractured.
19*	1.23	34.57	Shale, silty, grayish red, laminated at bottom and bluish gray in color at the top with a very thin silty dolomite bed in between.
18	1.40	35.97	Dolomite, light gray, very fine grained, medium bedded at the bottom and laminated at the top, with sandstone stringers in dolomite beds. Jointed and fractured.
17	0.50	36.47	Silty shale, bluish gray, laminated.
16	5.00	41.47	Alternate very thin to thin bedded sandstone and laminated shale, grayish red, very fine to fine grained. Shale increases towards the top where it becomes silty and unit is laminated at the top. 10 - 15% Shale.
15	4.15	45.62	Quartzitic sandstone, pale yellowish brown, very fine to fine grained, medium bedded at the bottom becoming thin and then very thin bedded at the top. Ripple marked and current laminated. Planolites.
14*	2.95	48.57	Sandy dolomite, medium gray, very fine grained, very thin to laminated becoming shaly at the top. <u>Rusophycus</u> and <u>Cruziana</u>. Current laminated.
13	1.50	50.07	Sandstone, grayish red, very fine grained, medium bedded, with an 8 cm. thick coarse grained sandstone bed in the middle; the unit becomes greenish gray in color at the top where the sandstone is quartzitic. Bottom beds are full of <u>Planolites</u> on lower bedding plane.
12	2.50	52.57	Sandstone, greenish gray, fine grained, thin bedded at the bottom with dolomite sandstone and sandy dolomite in the middle with bluish gray dolomite, shaly siltstone very thin to laminated with medium bedded sandstone at the top. Jointed and fractured.

Unit	Thickness In Meters	Cumulative Thickness	Description
11*	1.00	53.57	Alternate very thin sandstone and laminated shaly sandstone, grayish red, fine grained. Flaser bedding; ripple marked. Planolites 2 - 3 mm. wide.
10	1.50	55.07	Quartzitic sandstone, pale red, fine grained, thin to medium bedded. Jointed, looks massive.
9*	12.50	67.57	Alternate very thin to thin bedded sandstone and laminated shale, grayish red with occasional greenish gray sandstone beds, very fine to fine grained. 5% Shale. Current laminated. Flaser bedding in parts of the unit. Planolites on lower bedding of some beds.
8*	4.87	72.44	Alternate very thin bedded sandstone and laminated shaly to silty sandstone, grayish red and greenish gray laminae, very fine to fine grained, with greenish gray and grayish limonitic surfaces. Planolites are abundant on lower bedding of some beds. Some sandstone beds look modular. Bergaueria 3 cm. in diameter and 1.5 cm. deep.
7	1.13	73.57	Quartzitic sandstone, pale brown, very fine to fine grained, laminated at the bottom becoming very thin to thin bedded at the top with a limonitic weathered surface. Planolites 1 cm. wide on lower bedding plane of one bed.
6	2.58	76.15	Alternate quartzitic sandstone and silty sandstone, greenish gray with limonitic surfaces, very fine to fine grained laminated to very thin bedded. Some beds look modular.
5	3.60	79.75	Quartzitic sandstone, grayish orange with limonitic surfaces, very fine grained, very thin to thin bedded at the bottom with laminated greenish gray silty sandstone. A medium bedded sandstone is at the top of unit. Planolites; jointed looks massive. Silty sandstone is modular.

Unit	Thickness In Meters	Cumulative Thickness	Description
4	6.28	86.03	Alternate greenish gray silty sandstone and pale yellowish brown quartzitic sandstone with limonitic blotches, very fine to fine grained; very thick bedded with occasional thin to laminated beds; silty sandstone is more abundant upwards. Jointed, silty sandstone looks massive although some beds are laminated.
3	1.60	87.63	Sandstone, grayish red, very fine to fine grained, mostly thin to medium be bedded with occasional very thin to laminated shale. Fractured and jointed. Sandstone looks massive.
2	0.98	88.61	Shaly dolomite, dark gray very thin to laminated. Current laminated. Jointed.
1	1.00	89.61	Dolomitic sandstone, grayish orange, very fine to fine grained, thin to medium bedded. Fractured and jointed.

COPPER CREEK FAULT

BEAVER RIDGE - CRIPPEN GAP SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			PUMPKIN VALLEY SHALE
35	1.25	1.25	Sandstone, greenish gray, very fine to medium grained, very thin to thin bedded; salt and pepper texture due to the presence of glauconite in medium grained sandstone at the top. Unit looks massive, limonitic and hematitic weathered surface. Bergaucria found at the top of this unit 3 cm. in diameter 1 cm. deep.
34	2.55	3.80	Alternate very thin sandstone and laminated shaly sandstone, grayish to greenish gray, very fine to fine grained, reddish brown sandstone at the top and very thin dolomite beds in the middle. Some sandstone beds have internal laminations.
33/1*	2.50	6.30	Dolomitic sandstone, light gray, fine to medium grained, very thin bedded. Ripple marked; cross-bedding in opposite directions, some are truncated.
33/2	3.10	9.40	Sandstone, greenish gray, very fine to fine grained, very thin to medium bedded; sandstone is silty at the bottom; a grayish red sandstone bed in the middle 38 cm. thick, has two bands of Scoyenia laminated shale and sandstone at the top are flasered. Scoyenia in red bed and at the top of the unit; Planolites on lower bedding plane of some beds. Usually in thin to very thin sandstone beds.
32	1.85	11.25	Alternate quartzitic sandstone and shaly sandstone, greenish gray, very fine to fine grained, laminated to very thin bedded, bottom and top of unit, with 50 cm. of thin bedded quartzitic sandstone in the middle. Planolites ½ cm. to 1 cm. wide, in thin beds lower bedding plane.

Unit	Thickness In Meters	Cumulative Thickness	Description
31*	7.00	18.25	Sandy dolomite, dark to medium gray, thin to thick bedded, sand is very fine the whole unit is current laminated and cross-bedded. Skolithos are abundant especially in the middle of the unit; jointed.
30	1.65	19.90	Sandstone, dusky yellow, very fine to fine grained, laminated to thin but mostly very thin bedded, unit is more laminated at the top; top 60 cm. are deeply weathered. Sandstone is very much fractured and jointed, breaks into chips.
29*	3.00	22.90	Quartzitic sandstone, greenish gray to pale yellowish brown, very fine to fine grained, very thin to medium but mostly thin bedded, unit looks massive. Winding Planolites ½ cm. wide; ripple marked, some beds are current laminated.
28	1.95	24.85	Alternate laminated shale and very thin bedded sandstone, greenish gray to dusky yellow. Sandstone very fine to fine grained. 20% Shale.
27	1.10	25.95	Sandstone, grayish red to purplish, very fine to fine grained, thin bedded. Current laminated; badly fractured and jointed.
26*	2.45	28.40	Alternate sandstone and sandy shale, grayish red, very fine to medium grained, mostly laminated with occasional very thin beds; unit is flasered. Ripple marked; Rusophycus and Diplichnites are present at the top of the unit.
			FAULT
25*	1.65	30.05	Quartzitic sandstone, grayish red, fine grained, laminatd to very thin bedded; conglomeritic sandstone, greenish gray, 15 cm. thick is very thin bedded, and fine grained at the bottom. Ripple marked and current laminated.
24	1.45	31.50	Sandstone, grayish red, fine grained, laminated to medium bedded. Ripple marked and current laminated.

Unit	Thickness In Meters	Cumulative Thickness	Description
23/1*	2.00	33.50	Sandstone, silty, greenish gray, fine grained, laminated to very thin bedded, a thin bed 10 cm. thick is conglomeritic. Looks nodular.
23/2	2.00	35.50	Alternate sandstone and shaly sandstone, grayish red with grayish orange surface, laminated to very thin bedded, fine grained, glauconite is concentrated in very thin bands. Planolites ½ cm. wide on lower bedding of some beds.
23/3	0.60	36.10	Alternate very thin sandstone and laminated shale, grayish red, sandstone is very fine to fine grained, glauconite is abundant in very thin sandstone beds. Sandstone is current laminated, with micro cross-bedding in opposite direction.
23/4	0.78	36.88	Shaly glauconiticsandstone, greenish black, fine grained, and laminated.
22	1.80	38.68	Quartzitic sandstone, grayish red, very fine grained, thin bedded with laminated to very thin bedded shaly sandstone alternate with thin beds; bottom of unit is light grayish with grayish orange weathered surface. Ripple marks in some beds.
21	0.93	39.61	Alternate sandstone and shaly sandstone, grayish red to purplish, fine grained, very thin bedded; some beds have greenish gray bedding planes. Ripple marked.
20 *	0.70	40.31	Sandstone and silty sandstone greenish gray, fine grained, very thin to thin bedded; silty sandstone is modular; weathered surface is brownish gray.
19	1.15	41.46	Alternate very thin sandstone and laminated shaly sandstone, grayish red to purplish, sandstone is very fine to fine grained; bottom of unit there are 3 cm. of greenish gray shale. Flasered and ripple marked.

Unit	Thickness In Meters	Cumulative Thickness	Description
18*	2.65	44.11	Quartzitic sandstone, the bottom half is grayish red, while top half of unit is greenish gray; very fine to fine grained, very thin to thin bedded. There are 3 horizons of very coarse clean quartz sandstone, individual beds less than 7 cm. thick. Silty sandstone at the top is modular. Ripple marks in some beds; Planolites 3 mm. to ½ cm. wide and curved are on the lower bedding of some beds. Weathered surface of greenish gray sandstone is hematitic.
17	0.80	44.91	Silty to shaly sandstone, grayish red to brownish, very fine to fine grained, laminated to very thin bedded, but mostly laminated The beds on weathering break into square chips.
16*	1.57	46.48	Sandstone, grayish red, very fine to fine grained, laminated to thin bedded; some beds 10 cm. thick are lens shaped like a very shallow channel. Planolites on lower bedding plane of some beds; straight planolites in one bed are ½ cm. wide and 3 cm. long.
15	1.60	48.08	Quartzitic sandstone, greenish gray at the bottom and grayish red to purplish at the topl very fine to medium grained, laminated to medium bedded by mostly thin bedded. Current laminations and vertical worm burrows in some red beds at the top.
14	2.50	50.58	Alternate silty shale and glauconitic sandstone, grayish red and dark greenish gray respectively, sandstone is very fine to medium grained, mostly laminated with abundant very thin beds, greenish gray shale at the bottom and top of unit. Ripple marked; planolites 1 - 2 mm. wide and few cms. long on lower bedding planes of some beds. Unit is distorted and there is a fault through the unit.

Unit	Thickness In Meters	Cumulative Thickness	Description
13*	3.20	53.78	Alternate very thin and thin grayish red sandstone, and very thin to laminated greenish gray shaly sandstone; sandstone is fine grained, shaly sandstone beds are modular. Some beds are flasered; ripple marked, about 8 cm. wide; Planolites on upper bedding plane of some beds; Cruziana.
12	2.50	56.28	Alternate sandstone and shaly sandstone, grayish red, very fine to medium grained, mostly laminated with abundant very thin beds. Ripple marked and flasered.
11*	2.75	59.03	Sandstone, grayish red at the bottom, grayish orange and greenish gray at the top, very fine to coarse grained; very thin to thin bedded; two horizons of very coarse sandstone each 5 cm. thick one in the middle and the other 50 cm. above; top beds look modular. Mud cracks in bottom bed. Planolites ½ cm. wide straight and winding on upper bedding plane of some beds.
10	0.95	59.98	Alternate shaly to silty sandstone and sandstone, grayish red, very fine to fine grained, mostly laminated with abundant very thin beds. Flasered.
9*	2.35	62.33	Sandstone, grayish red, very fine to fine grained, laminated to thin bedded with intervening very thin bedded shaly sandstone; unit slightly distorted. Ripple marked; mud cracks in a 10 cm. thick bed. Positive and negative small mounds or bumps on upper and lower bedding planes. Holes or burrows ½ cm. wide on upper bedding plane. Planolites 2 mm. wide few cms. long.
8	3.12	65.45	Quartzitic sandstone, greenish gray, very fine to fine grained, laminated to medium bedded with 50 cm. of grayish red thin bedded sandstone in the middle. Ripple marked; mud cracks in red sandstone.

Unit	Thickness In Meters	Cumulative Thickness	Description
7	6.75	72.20	Sandstone, very thin to thin bedded alternating with laminated shale; sandstone is very fine to medium grained; glauconite is found in medium to coarse grained sandstone beds close to bottom, clean lenses of coarse sandstone, whitish in color 5 cms. thick at the top of the unit. 5% Shale. Unit slightly distorted; ripple marked; Planolites on lower bedding planes of some beds. Rusophycus found in debris.
6	2.20	74.40	Alternate sandstone and shaly sandstone, dark greenish to grayish red, fine grained, laminated to very thin bedded; some sandstone beds are glauconitic. Current laminations in sandstone beds; flasered. 10% Shale
			FAULT
5	5.95	80.35	Dolomite and dolomitic sandstone, medium gray to moderate yellowish brown, very fine grained, laminated to medium bedded, but mostly thin bedded; sandstone stringers are found in the dolomite. Shaly dolomite top of unit. Skolithos 1 - 2 mm. wide and 1 - 2 cms. long are found in dolomitic sandstone. Unit is faulted, jointed and fractured.
4	1.80	82.15	Dolomite, medium gray, microcrystalline to very fine, laminated to thin bedded. Current laminated; jointed; weathered surface, pale yellowish brown.
3*	3.00	85.15	Sandstone, grayish red, very fine to fine grained, laminated to thin bedded; light gray very thin bedded sandstone close to bottom of unit. Current laminated and micro-cross-bedding; jointed; planolites on lower bedding plane of some red beds. Ripple marked.
2	1.20	86.35	Dolomite and dolomitic sandstone, medium gray, very fine grained, laminated to very thin bedded; some shaly dolomite at the top, and a 5 cm. thick grayish red sandstone bed in the middle of the unit.

Unit	Thickness In Meters	Cumulative Thickness	Description
			Planolites 2 mm. thick and mostly less than 3 cms. long in some beds.
1	5.00	91.35	Dolomite, dark gray, very fine thin to medium bedded, sandstone stringers 1 cm. to 3 cm. thick are abundant; differential weathering cause the stringers to stand out. Unit is faulted, jointed and brecciated at the bottom. Some sandstone stringers look like intraclasts.
			BEAVER VALLEY FAULT

SHARP RIDGE - FIRST CREEK SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			PUMPKIN VALLEY SHALE
24	4.00	4.00	Alternate laminated shale and laminted to very thin bedded sandstone, fine grained, pale olive and greenish gray with occasional pale red horizons of shale and sandstone, with glauconitic laminations with limonitic surfaces. Rome exposure is partly eroded and covered in this section at the top.
23/1	0.50	4.50	Glauconitic sandstone, pale brown to grayish red, fine to medium grained, with a limonitic surface. 5% Shale. Current laminations of glauconite and white quartz sandstone. Shale is distorted.
23/2	1.25	5.75	Alternate very thin bedded sandstone and laminated shale, pale yellowish brown, fine grained sandstone; shale is dominant at the bottom, flaky and friable. 30% Shale. Flaser bedding at the bottom.
22	0.50	6.25	Shale, greenish gray, thinly laminated, flaky and friable with two very thin bedded, fine grained sandstone beds at the top.
21	0.75	7.00	Alternate, very thin bedded sandstone and laminated shale, pale red, very fine to medium grained sandstone. Some sandstone beds are glauconitic with limonitic blotches. 20% Shale. Fine _Planolites_ and fecal pellets on some beds. Drag folding.
20*	0.75	7.75	Glauconitic sandstone, pale brown with a dark greenish tinge, fine to coarse grained, salt and pepper texture in the coarse grained sandstone, very thin to thin bedded with shaly bedding planes. Looks flasered at the bottom of unit.

Unit	Thickness In Meters	Cumulative Thickness	Description
19	1.65	9.40	Alternate very thin bedded sandstone and laminated shale, pale brown to medium yellowish brown, fine to medium grained glauconitic sandstone beds. 10% Shale. Current glauconitic laminations in sandstone beds.
18	5.00	14.40	Alternate very thin bedded sandstone and laminated shale, pale brown with a dark greenish gray tinge, sandstone is very fine grained except where it is glauconitic it is fine to medium grained; glauconite is abundant at the top. 10% Shale. Drag folding distorted the unit completely.
			FAULT
17	0.50	14.90	Shale, greenish gray, thinly laminated, flakey and friable occasional laminated very fine grained sandstone.
16	9.00	23.90	Alternate very thin bedded sandstone and laminated shale, pale brown, fine grained with occasional medium grained glauconitic sandstone beds; occasional shale beds 15 - 25 cm. thick. 30 - 40% Shale. Some sandstone beds are current laminated with alternate glauconite and sandstone laminae.
15	0.70	24.60	Shale, pale brown, thinly laminated, flakey and friable.
14/1*	0.25	24.85	Sandstone, dark yellowish orange, very fine grained, thin bedded; slightly glauconitic. Current laminated at the bottom.
14/2	0.65	25.50	Shale alternating with very thin to laminated sandstone, very fine grained, pale olive and pale brown, with two horizons of glauconitic sandstone at the top. 40 - 50% Shale. Ripple marked, micro cross-bedding. Current laminations in some beds. Vertical dip.

Unit	Thickness In Meters	Cumulative Thickness	Description
14/3	2.48	27.98	Alternate very thin bedded sandstone and laminated shale olive gray with occasional glauconitic sandstone, mostly very fine grained with occasional medium grained sandstone. 30% Shale. Fine internal laminations in sandstone. Flaser bedding in the middle.
14/4	0.28	28.26	Shale, light olive gray, flakey and friable with few very thin bedded very fine sandstone beds.
14/5	0.38	28.64	Sandstone, dark yellowish orange with greenish gray bedding planes, very fine grained very thin to thin bedded. Current laminated; fractured and jointed.
13/1	0.60	29.24	Alternate laminated shale and very thin bedded sandstone, pale brown, fine grained; 65% shale at the top and 10% at bottom, 50% shole unit. Mud cracks in sandstone beds at the bottom. Fine Planolites and fecal pellets.
13/2	0.40	29.64	Shale, grayish brown, thinly laminated, flakey and friable.
13/3	1.65	31.29	Alternate very thin bedded sandstone and laminated shale, pale brown, very fine to fine grained; occasional glauconitic sandstone horizons. 20% Shale. Mud cracks; fine internal laminations.
13/4	0.20	31.54	Shale, grayish brown, thinly laminated, flakey and friable.
12/1	0.23	31.77	Glauconitic sandstone, greenish gray with limonitic surfaces at the top, very fine to medium grained, very thin to thin bedded with shaly bedding planes. Current laminated, micro cross-bedding.
12/2	0.55	32.32	Sandstone, greenish gray, very fine to fine grained, very thin to laminated. 5% Shale. Current laminations.

Unit	Thickness In Meters	Cumulative Thickness	Description
12/3	0.60	32.92	Glauconitic sandstone, greenish gray, very fine grained with occasional medium grained sandstone, very thin bedded with occasional laminated and thin beds. 10% Shale. Current laminated, micro cross-bedding. Flaser bedding bottom of unit. Salt and pepper texture in some beds.
11/1*	0.65	33.57	Dolomite, medium light gray, thin bedded with greenish gray bedding planes and light brown gray very fine grained dolomitic sandstone. Current laminated.
11/2	0.25	33.82	Sandstone, dark greenish gray very fine grained, very thin to laminated. Fine irregular internal laminations due to shale.
11/3	0.85	34.67	Dolomite, medium light gray, thin to medium bedded, with very fine grained sandstone laminations about 2 cm. thick in dolomite beds.
10*	0.25	34.92	Alternate very thin bedded sandstone and laminated shale, dark greenish gray very fine grained sandstone, a thin dolomite bed at the bottom of unit. Mud cracks in dolomite beds. Shaly bedding planes are shiny.
9	1.85	36.77	Dolomite, medium light gray, thin to medium bedded, with a grayish orange weathered surface and greenish gray bedding planes; white very fine grained sandstone stringers are clear in dolomite.
8/1*	0.85	37.62	Quartzitic sandstone, greenish gray with a pinkish tinge, very fine grained, laminated to thin bedded. Ripple marked, fine internal laminations due to the presence of shale.
8/2	0.50	38.12	Quartzitic sandstone, light olive gray, very fine to fine grained, laminated to very thin bedded withlaminated shale at the top. 10% Shale. Flaser bedding at the top; fine glauconitic laminations in some beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
7	0.75	38.87	Sandstone, medium dark gray, very fine grained, very thin bedded with occasional laminated and thin beds, with a thin dolomitic sandstone bed at the bottom. Planolites on some beds.
6	0.55	39.42	Alternate very thin bedded quartzitic sandstone and laminated shale, light o olive gray, very fine grained. 30% Shale. Flaser bedding; ripple marked.
5/1	0.25	39.67	Quartzitic sandstone, dark gray, very fine grained, very thin bedded. Ripple marked.
5/2	0.13	39.80	Dolomite, medium gray, thin bedded with very fine grained white sandstone stringers.
5/3	1.48	41.28	Quartzitic sandstone, medium light gray very fine grained, very thin to medium bedded with limonitic blotches; some beds in the middle are glauconitic.
5/4	0.18	41.46	Sandstone, dusky yellow, very fine to fine grained, laminated to very thin bedded. Ripple marked; flaser bedding.
4	0.43	41.89	Quartzitic sandstone, white very fine grained, thin to medium bedded. Fractured and jointed.
3	4.55	46.44	Dolomite sandy, medium light gray, very fine grained, medium to thick bedded. Fractured and jointed. Dolomite with sandstone stringers in fault contact on top of this unit.
			FAULT
2	0.55	46.99	Dolomite sandy, medium bluish gray, very fine grained, medium bedded. Fractured and jointed; dark internal laminations.
			FAULT

Unit	Thickness In Meters	Cumulative Thickness	Description
1/1	5.55	52.54	Dolomite sandy, medium dark gray, very fine grained very thick to medium bedded; some beds show stringers of pure sandstone; weathered surface is light brownish gray. Fractured and jointed. Major fault 4 meters from bottom.
			SALTVILLE FAULT

SHARP RIDGE - SHARP GAP SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			Grayish red and greenish gray shale, shaly sandstone and siltstone, laminated to very thin bedded, folded and faulted, completely distorted. It is difficult to determine if this is part of the Pumpkin Valley Shale.
48/1*	0.50	0.50	Siltstone, moderate yellowish brown, very thin bedded to laminated. Glauconitic dark greenish gray laminae.
48/2	0.05	0.55	Glauconitic sandstone, greenish black, medium to coarse grained, thin bed which wedges out. Cross bedded with alternate glauconite and quartz laminae, cross beds are truncated at the top.
48/3	0.09	0.64	Quartzitic sandstone, pale yellowish brown, very fine grained very thin bedded with occasional olive gray thinly laminated shale. Fine internal glauconitic laminae; ripple marked.
48/4	0.05	0.69	Shale, light olive gray, thinly laminated.
48/5	0.35	1.04	Sandstone, grayish orange, very fine grained, very thin bedded with greenish gray bedding planes. Fine internal glauconitic laminae. Planolites on lower bedding planes of some beds.
48/6	0.03	1.07	Sandstone, light olive gray very fine grained, very thin bed.
48/7	0.05	1.12	Sandstone, grayish orange, very fine grained, very thin bedded. Fine internal glauconitic laminae.
48/8	0.05	1.17	Shale, light olive gray, thinly laminated, with very fine grained sandstone lenses. Flaser bedding.

Unit	Thickness In Meters	Cumulative Thickness	Description
47/1	0.18	1.35	Siltstone, pale brown, very thin bedded with laminated light olive gray shale. Light brown weathered surface. Sharp upper and lower contacts.
47/2	0.23	1.58	Shaly siltstone, dark yellowish orange, very thin bedded with light olive gray laminated shale.
47/3	0.55	2.13	Siltstone, pale brown, very thin evenly bedded, with grayish yellow green bedding planes. Worm trails and <u>planolites</u> on bedding planes.
47/4	0.25	2.38	Shaly siltstone, pale brown, very thin bedded, with grayish red shaly bedding planes. Irregular shaly laminations. Fine mud cracks. <u>Planolites</u> 2 - 3 mm. wide.
47/5	0.18	2.56	Sandstone, moderate yellowish brown, thin bedded very fine grained, with grayish olive laminated shale.
46/1*	0.50	3.06	Sandstone, moderate yellowish brown, very fine grained, thin to medium bedded. Current laminated.
46/2	0.29	3.35	Silty clay, light brown to moderate brown, laminated with sharp upper and lower contacts. Unit is probably deeply weathered carbonate rock.
46/3	0.24	3.59	Sandstone, moderate yellowish brown, very fine grained, thin bedded. Current laminated. Weathered surface is grayish.
46/4	0.75	4.34	Sandstone, medium yellowish brown, fine to medium grained, thin to very thin bedded with occasional laminated beds.
45	1.00	5.34	Shaly sandstone, light olive gray, fine to medium grained, laminated interbedded with moderate yellowish brown, laminated fine grained sandstone. Sandstone beds are current laminated. Flaser bedding at the bottom with increase in percentage of shale.

Unit	Thickness In Meters	Cumulative Thickness	Description
44/1	0.25	5.59	Siltstone, grayish orange, very thin bedded. Ripple marked.
44/2	0.08	5.67	Silty clay, dark yellowish orange, laminated. Deeply weathered.
44/3	0.13	5.80	Sandstone, moderate yellowish brown, very fine grained, very thin bedded with occasional laminated shale. 5% Shale. Ripple marked.
44/4	1.33	7.13	Sandstone, grayish orange to moderate yellowish brown, very fine grained, very thin bedded with thin beds at the bottom and middle with light olive gray shaly bedding planes. Ripple marked; micro cross-bedding with alternate sand and glauconite laminae; current laminated.
44/5	0.13	7.26	Silty shale, light olive gray laminated alternating with laminated very fine grained grayish orange sandstone.
44/6	0.45	7.71	Sandstone, grayish orange to moderate yellowish brown, very fine grained, thin bedded. Current laminated with glauconitic laminae.
44/7	0.05	7.76	Sandstone, light olive gray very fine grained, laminated. Current laminated, glauconitic laminae.
44/8	0.25	8.01	Sandstone, grayish orange to moderate yellowish brown, very fine grained, evenly thin bedded. Ripple marked.
44/9	0.05	8.06	Sandstone, light olive gray, fine to medium grained, laminated. Fine internal glauconitic laminae.
44/10	0.10	8.16	Sandstone, moderate yellowish brown, very fine grained, thin bedded. Current laminated.

Unit	Thickness In Meters	Cumulative Thickness	Description
44/11	0.13	8.29	Sandstone, pale yellowish brown to light olive gray, fine to medium grained, laminated to very thin bedded. Current laminated, alternate dark and light laminae. Planolites.
43/1 *	0.38	8.67	Siltstone, grayish orange, thin to medium bedded. Fractured.
43/2	0.30	8.97	Sandstone, grayish orange, very fine grained, very thin to laminated.
42/1	0.10	9.07	Siltstone, dark yellowish orange, laminated. Dark and light internal laminae.
42/2	0.33	9.40	Siltstone, dark yellowish brown, laminated to very thin bedded. Current laminated, dark and light laminae.
42/3	0.18	9.58	Siltstone, grayish orange, laminated. Alternate dark and light laminae.
42/4	0.10	9.68	Siltstone, light brown, laminated. Deeply weathered, internal laminations are preserved.
41 *	1.38	11.06	Sandstone, moderate yellowish brown, very fine to fine grained, thin to medium bedded; sharp upper and lower contacts. Some beds are porous probably due to teaching of carbonates. Current laminated. Jointed.
40/1	0.05	11.11	Siltstone, bluish white, laminated
40/2	1.40	12.51	Sandstone, light brown, fine grained, laminated, unit is porous probably due to leaching of carbonates. Deeply weathered.
39/1*	1.83	14.34	Sandstone, grayish orange to moderate yellowish brown, fine grained, thin bedded with occasional laminated and medium beds. Fractured and jointed breaks to small cubes. Current laminated.

Unit	Thickness In Meters	Cumulative Thickness	Description
39/2	0.25	14.59	Silty clay, pale brown, laminated. Deeply weathered.
39/3	0.58	15.17	Sandstone, dark yellowish brown, fine grained, thin bedded.
			FAULT
39/4	0.13	15.30	Sandstone, pale greenish yellow, fine grained, thin bedded. Brecciated.
39/5	0.05	15.35	Silty clay, moderate brown, laminated with black streaks. Deeply weathered.
39/6	0.40	15.75	Sandstone, moderate yellowish brown, fine grained, very thin to thin bedded. Jointed, some beds are porous.
38*	0.83	16.58	Quartzitic sandstone, very pale orange to dark yellowish orange, fine grained. medium bedded. Current laminated, laminae are in bands 1 cm. to 5 cm. thick. Fractured and jointed.
37/1	0.25	16.83	Siltstone, dark yellowish orange laminated. Deeply weathered limonitic color.
37/2	0.30	17.13	Sandstone, grayish orange, fine grain, very thin to thin bedded. Ripple marked.
37/3	0.13	17.26	Shaly siltstone, light olive gray, thinly laminated. Friable, micaceous, , rusty mottled surface.
36*	1.70	18.96	Quartzitic sandstone, greenish gray, fine to medium grained, medium bedded. Current laminated with alternate dark and light laminae. Planolites common.
35	0.65	19.61	Sandstone, pale brown, very fine grained, laminated to very thin bedded with light olive gray shaly bedding planes. Mud cracks, ripple marks; Planolites.

Unit	Thickness In Meters	Cumulative Thickness	Description
34/1	0.45	20.06	Silty shale, light olive, gray, to dusky yellow, laminated.
34/2	0.20	20.26	Clayey siltstone, dark yellowish orange, laminated to very thin bedded. Deeply weathered to a limonitic color.
34/3	0.35	20.61	Siltstone, greenish gray to grayish orange, laminated.
34/4	0.05	20.66	Siltstone, bluish white, laminated.
34/5	0.15	20.81	Sandstone, moderate yellowish grown, very fine grained, very thin bedded. Weathers into small cubes.
34/6	0.15	20.96	Shaly siltstone, pale olive to dusky yellow, laminated. Looks flasered.
34/7	0.10	21.06	Clayey siltstone, dark yellowish orange, laminated. Deeply weathered.
33	1.00	22.06	Sandstone, grayish orange, very fine grained, very thin to medium bedded. Fractured and jointed. Planolites in one bed.
32/1	0.13	22.19	Shale, light olive gray, laminated. Friable.
32/2	0.18	22.37	Shaly siltstone, dark yellowish orange, laminated with dark streaks. Deeply weathered to a limonitic color.
32/3	0.43	22.80	Sandstone, grayish orange and mottled pale olive, very fine grained, very thin bedded. Completely shattered masking the bedding.
32/4	0.45	23.25	Sandstone, grayish orange, very fine grained, medium bedded. Fractured and jointed.
32/5	0.25	23.50	Siltstone, dark yellowish orange, very thin to laminated. Deeply weathered to a limonitic color.

Unit	Thickness In Meters	Cumulative Thickness	Description
32/6	0.20	23.70	Sandstone, grayish orange, very fine grained, laminated to very thin bedded. Ripple marked.
32/7	0.15	23.85	Sandy shale, light olive gray laminated with lenses of very fine grained sandstone. Flaser bedding.
31/1*	0.85	24.70	Quartzitic sandstone, grayish orange to moderate yellowish brown, very fine grained, medium bedded. Fractured and jointed.
31/2	0.08	24.78	Shaly siltstone, light olive gray laminated. Alternate dark and light internal laminae.
31/3	0.35	25.13	Sandstone, grayish orange to moderate yellowish brown, very fine grained, medium bedded. Fractured and jointed.
31/4	0.25	25.38	Sandstone, pale yellowish brown fine grained, thin bedded with grayish yellow green bedding planes. Ripple marked.
30/1*	0.45	25.83	Sandstone, grayish red, very fine grained, laminated to very thin bedded with grayish green bedding planes. Planolites 1.5 cm. wide and smaller are abundant; some bands are bioturbated.
30/2	0.10	25.93	Sandstone, moderate yellowish brown, very fine grained, very thin bedded.
30/3	0.13	26.06	Shaly siltstone, grayish red, laminated.
30/4	0.13	26.19	Silty shale, light olive gray, laminated. Calcite veins parallel to bedding.
30/5	0.20	26.39	Shaly siltstone, pale olive, laminated, with 5 cm. of laminated shale at the bottom. Calcite veins 2 mm. thick parallel to bedding. Arthrophycus?
30/6	0.10	26.49	Sandstone, light brown, very fine grained, laminated.

Unit	Thickness In Meters	Cumulative Thickness	Description
30/7	0.13	26.62	Sandstone, moderate yellowish brown, very fine grained, laminated to very thin bedded.
30/8	0.08	26.70	Shaly sandstone, dusky yellow, very fine grained, laminated. Ripple marked.
30/9	0.13	26.83	Sandstone, light brown, very fine grained, laminated with black and light colored streaks.
30/10	0.15	26.98	Sandstone, moderate yellowish brown, very fine grained, very thin bedded with pale olive bedding planes.
30/11	0.13	27.11	Shaly sandstone, with light olive gray laminated shale and grayish orange, laminated very fine grained sandstone. Flaser bedding.
30/12	0.10	27.21	Siltstone, pale yellowish orange, laminated. Deeply weathered.
30/13	0.05	27.26	Silty shale, light olive gray, laminted. Sharp lower contact.
29/1	0.35	27.61	Quartzitic sandstone, moderate yellowish brown, fine grained, medium bedded, glauconitic at the bottom. Fractured and jointed.
29/2*	0.08	27.69	Quartzitic sandstone, light olive gray, fine grained, laminated to very thin bedded, with pale olive bedding planes. *Planolites* abundant.
29/3	0.05	27.74	Sandstone, moderate yellowish brown, fine grained, very thin bedded. Current laminated with dark laminae.
28/1	0.10	27.84	Shale, light olive gray, laminated. Friable.
28/2	0.20	28.04	Shaly siltstone, dusky yellow to yellowish gray, laminated.
28/3	0.03	28.07	Shale, light olive gray, laminated.
27/1	0.08	28.15	Shaly, grayish red, thinly laminated. Friable.

Unit	Thickness In Meters	Cumulative Thickness	Description
27/2	0.23	28.38	Sandstone, grayish red to moderate brown, very fine grained, laminated with intervening laminated shale. 30% Shale
27/3	0.05	28.43	Sandstone, grayish red, fine grained, thin bed.
27/4	0.23	28.66	Shaly sandstone, grayish red, very fine grained, laminated.
27/5	0.05	28.71	Sandstone, grayish red, very fine grained, thin bed.
27/6	0.45	29.16	Shaly sandstone, grayish red, very fine grained, laminated with three, very fine grained very thin sandstone beds.
26/1	0.28	29.44	Sandstone, grayish red, very fine grained, medium bed with pale olive upper bedding plane.
26/2	0.23	29.67	Sandstone, grayish red, very fine grained, very thin bedded with occasional laminated shaly sandstone beds.
26/3	0.28	29.95	Shaly sandstone, grayish red, very fine grained, laminated.
26/4	0.58	30.53	Sandstone, grayish red, very fine grained, very thin bedded with occasional laminated shaly sandstone.
26/5	0.03	30.56	Sandstone, grayish yellow green, very fine grained, laminated.
25	0.88	31.44	Quartzitic sandstone, grayish orange to moderate yellowish brown, fine grained, thin to medium bedded. <u>Planolites</u> bottom of unit. Jointed.
24/1	0.10	31.54	Shale, pale olive, laminated.
24/2	0.25	31.79	Sandstone, grayish red, very fine grained, laminated alternating with laminated shale. 25% Shale. Flaser bedding; current laminated with alternate dark and light laminae.

Unit	Thickness In Meters	Cumulative Thickness	Description
23	1.13	32.92	Quartzitic sandstone, pale brown, very fine grained, thin to medium bedded; pale olive bedding planes. Jointed. Sharp lower and upper contacts.
22/1*	0.73	33.65	Sandstone, grayish red, very fine grained, very thin to thin bedded with 1.5 cm. thick horizon of olive gray shale at the top and two 3 cm. thick horizons of grayish red shale at the bottom. Current laminated.
22/2	0.03	33.68	Sandy shale, grayish red, laminated.
22/3	0.05	33.73	Sandstone, grayish red, very fine grained, thin bed. Current laminated.
22/4	0.05	33.78	Sandy shale, grayish red, very fine grained, laminated.
22/5	0.05	33.83	Sandstone, grayish red, very fine grained, thin bed. Current laminated.
22/6	0.13	33.96	Shale, grayish red, laminated alternating with very fine grained, laminated sandstone. 60% Shale. Flaser bedding.
22/7	0.25	34.21	Sandstone, grayish red, very fine grained, very thin bedded. Current laminated.
22/8	0.28	34.49	Sandstone, grayish red, very fine grained, laminated alternating with laminated shale. 30% Shale. Current laminated; micro cross-bedding. Planolites are abundant.
22/9	0.15	34.64	Sandstone, grayish red to blackish red, fine to medium grained, medium bed. Planolites lower bedding plane; bioturbated at the bottom; current laminated vertical burrows.

Unit	Thickness In Meters	Cumulative Thickness	Description
22/10	0.18	34.82	Sandstone, grayish red to blackish red, fine to medium grained, thin bedded. Micro cross-bedding in opposite directions. Planolites abundant on bedding planes.
22/11	0.68	35.50	Glauconitic sandstone, olive gray to moderate yellowish brown, fine to medium grained, laminated to thin bedded with occasional shale and sandy shale. Current laminated; micro cross-bedding; planolites are abundant. Salt and pepper texture.
21/1*	1.75	37.25	Shale, dark greenish gray, to pale olive, laminated, alternating with laminated moderate reddish brown, fine to medium grained glauconitic sandstone. 50% Shale. Planolites 2 mm. wide and short are abundant. Salt and pepper texture in sandstone.
21/2	0.73	37.98	Sandstone, pale brown, very fine grained, very thin to laminated alternating with greenish black glauconitic sandstone. Very fine internal dark and light laminae in glauconitic sandstone.
21/3	0.03	38.01	Shale, light olive gray, thinly laminated. Flakey and friable.
21/4	0.18	38.19	Alternate laminated light olive gray shaly sandstone and pale brown sandstone, very fine grained. Current laminated, some beds are burrowed.
21/5	0.03	38.22	Shale, grayish red, thin laminated. Flakey and friable.
21/6	0.38	38.60	Glauconitic sandstone, greenish black, fine to medium grained, laminated to very thin bedded. Current laminated. Lower half of unit has a grayish red surface.
21/7	0.33	38.93	Glauconitic sandstone, light gray to light olive gray, fine to medium grained, laminated.

Unit	Thickness In Meters	Cumulative Thickness	Description
20/1	0.35	39.28	Quartzitic sandstone, pale yellowish brown, very fine grained, very thin to thin bedded with pale olive bedding planes. Current laminated.
20/2	0.33	39.61	Quartzitic sandstone, pale brown to grayish red, very fine grained, very thin to thin bedded. Some beds are lens shaped. Ripple marks; current laminated.
20/3	0.35	39.96	Quartzitic sandstone, moderate yellowish brown, very fine grained, thin bedded. Current laminated.
19/1*	0.88	40.84	Sandstone, grayish red, very fine grained, very thin bedded alternating with shale and shaly sandstone, very fine grained and laminated. Mud cracks; asymmetric ripple marks, current direction is SE. Current laminated; micro cross-bedding; flaser bedding in the middle. <u>Planolites</u> are abundant.
19/2	0.35	41.19	Sandstone, grayish red, very fine grained, thin bedded with occasional very thin beds. Ripple marked; <u>Planolites</u> are common. Rusophycus is present.
19/3	0.28	41.47	Sandstone, grayish red, fine to medium grained thin bedded with laminated to very thin bedded shaly sandstone. Ripple marked; some laminations are bioturbated. Planolites 2 mm. wide are abundant. <u>Rusophycus</u>?
19/4	0.35	41.82	Quartzitic sandstone grayish red, very fine grained, very thin bedded, alternating with laminated pale olive, fine to coarse grained shaly sandstone. Some beds are bioturbated. Planolites of different sizes are abundant. Shaly sandstone is glauconitic.
18/1	0.05	41.87	Sandstone, grayish red, very fine grained, thin bed. Asymmetric ripple marks, current direction S20°E.

Unit	Thickness In Meters	Cumulative Thickness	Description
18/2	0.50	42.37	Shale, grayish red, thinly laminated with a very thin, very fine grained sandstone bed in the middle. Flakey and friable. Sandstone bed is current laminated with micro cross-bedding.
18/3	0.53	42.90	Laminated shale and shaly sandstone, grayish red, very fine grained with light olive gray bedding planes.
18/4	0.28	43.18	Sandstone, pale yellowish brown, very fine-grained, laminated alternating with light olive gray laminated shale and shaly sandstone. Flaser bedding.
17/1*	0.90	44.08	Quartzitic sandstone, glauconitic, light olive gray to pale yellowish brown, the upper half is fine grained, the lower half is coarse grained, thin bedded. Upper beds are current laminated. Quartz grains are rounded.
17/2	0.20	44.26	Sandstone, grayish orange at the top to moderate yellowish brown at the bottom. Very fine grained laminated to very thin bedded. Current laminated.
16/1	0.15	44.43	Sandstone, moderate yellowish brown, very fine grained, laminated alternating with thinly laminated dark greenish gray shale. Flaser bedding. Sandstone is dominant.
16/2	0.08	44.51	Shale, dusky yellow green, thinly laminated.
16/3	0.18	44.69	Shale, grayish red to grayish brown, thinly laminated. Flakey and friable.
15/1	0.10	44.79	Shaly siltstone, grayish yellow, laminated. Current laminated.
15/2	0.13	44.92	Sandstone, moderate yellowish brown, very fine grained, laminated to very thin bedded. Current laminated; micro cross-bedding.

Unit	Thickness In Meters	Cumulative Thickness	Description
15/3	0.25	45.17	Sandstone, grayish brown, fine grained, laminated alternating with laminated, very fine grained pale brown shaly sandstone. Sandstone is current laminated.
15/4	0.08	45.25	Sandstone, moderate yellowish brown to dark yellowish brown very fine grained, thin bed.
15/5	0.55	45.80	Silty shale, grayish red, laminated. Laminated transverse and parallel calcareous veins.
15/6	0.08	45.88	Siltstone, grayish orange pink, thin bed.
14/1	0.18	46.06	Shale, silty, dark greenish gray, laminated.
14/2	0.10	46.16	Sandstone, dusky yellow to yellowish gray, very fine grained, laminated.
14/3	0.18	46.34	Sandstone, grayish brown, very fine grained, laminated with intervening dark greenish gray, laminated shale. 25% Shale. Flaser bedding; current laminated sandstone. Some beds are burrowed.
13/1*	0.78	47.12	Sandstone, grayish red, very fine grained, very thin bedded with laminated shaly sandstone. Ripple marked; current laminated; Planolites abundant; Rusophycus.
13/2	0.35	47.47	Sandstone, pale brown to grayish brown, very fine grained laminated with intervening laminated shaly sandstone. Planolites 2 mm. wide are abundant.
13/3	0.10	47.57	Siltstone, yellowish gray, thin bed with discontinuous lenses of dark greenish gray shale.
13/4	0.40	47.97	Sandstone, dark greenish gray very fine grained, laminated with intervening shaly sandstone.

Unit	Thickness In Meters	Cumulative Thickness	Description
13/5	0.68	48.65	Sandstone, grayish red to blackish red, very fine grained, very thin to laminated. Planolites on lower bedding plane. Rusophycus.
13/6	0.23	48.88	Sandstone, greenish gray to light olive gray, very fine grained, very thin bedded with laminated shaly sandstone. Ripple marked; flaser bedding. Planolites.
12/1*	0.60	49.48	Quartzitic sandstone, pale yellowish brown to pale brown, fine grained, thin to very thin bedded with light olive gray upper bedding planes.
12/2	0.23	49.71	Sandstone, grayish red, fine to medium grained, thin bedded. Current laminated.
12/3	0.15	49.86	Sandstone, grayish green mottled with pale brown, coarse grained, with lenses of fine grained sandstone; thin bedded.
12/4	0.18	50.04	Sandstone, light olive gray, very fine grained, laminated to very thin bedded. Nodular weathering.
12/5	0.18	50.22	Sandstone, pale olive, coarse grained, thin bedded with very fine grained internal laminae. Conglomeritic sandstone.
12/6	0.15	50.37	Sandstone, moderate yellowish brown, very fine grained, very thin to thin bedded. Current laminated, laminae are dark colored.
12/7	0.13	50.50	Sandstone, light olive gray to grayish olive, very fine grained, laminated.
12/8	0.10	50.60	Quartzitic sandstone, pale yellowish brown to pale olive at the bottom, very fine grained, thin bedded.
12/9	1.30	51.90	Quartzitic sandstone, light gray to grayish orange pink, very fine grained, thin to medium bedded. Current laminated, with alternate dark and light laminae.

Unit	Thickness In Meters	Cumulative Thickness	Description
12/10	0.30	52.20	Quartzitic sandstone, light gray to grayish green, very fine grained, thin bedded. Current laminated.
11/1*	0.28	52.48	Sandstone, grayish red, coarse to very coarse grained, thin bedded.
11/2	0.05	52.53	Sandstone, grayish red, very fine grained, very thin bed. Planolites abundant on lower bedding plane.
11/3	0.13	52.66	Sandstone, grayish red, very fine grained, laminated.
11/4	0.73	53.39	Sandstone, grayish red, fine grained, with coarse to very coarse quartz grains scattered in the matrix, very thin to thin bedded. Some beds wedge out. Planolites abundant on lower bedding plane.
11/5	0.08	53.47	Silty sandstone grayish red, very fine grained, laminated.
11/6	0.05	53.52	Sandstone, grayish red, very fine grained, very thin bed. Current laminated.
11/7	0.80	54.32	Sandstone, grayish red, fine grained, with lenses of coarse to very coarse quartz sandstone 2 mm. to 1 cm. thick some lenses are 8 cm. thick, glauconitic and greenish gray in color; medium bedded with some thin beds. Current laminated. Some beds are bioturbated; vertical burrows; planolites 2 mm. wide in some beds.
10/1*	0.05	54.37	Glauconitic sandstone, greenish black, coarse grained, thin bed.
10/2	0.08	54.45	Sandstone, brownish gray to dark greenish gray, fine grained with occasional coarse grained laminae; laminated. Micro cross-bedding truncated; current laminated with glauconitic laminae.

Unit	Thickness In Meters	Cumulative Thickness	Description
10/3	0.25	54.70	Silty sandstone, grayish red, with a greenish black weathered surface, very fine grained, laminated. Unit looks like one medium bed.
10/4	1.05	55.75	Sandstone, grayish red to greenish black with lower beds lighter in color and are greenish gray, fine grained, very thin to thin bedded, with internal glauconitic laminae. Current laminated with alternate dark and light laminae. Micro cross-bedding. <u>Skolithos</u> 5 mm. wide, some stopping at a change in color.
9/1*	0.60	56.35	Sandstone, grayish red, very fine grained, laminated to very thin bedded; greenish black bedding planes. Current laminated, with wavy laminae.
9/2	2.15	58.50	Sandstone, dark greenish gray, very fine grained, laminated to very thin bedded with shaly bedding planes. 10% Shale. Current laminated with internal glauconitic laminae, some laminae are wavy.
9/3	0.80	59.30	Sandstone, light olive gray to greenish gray with some moderate yellowish brown sandstone, very fine grained, laminated alternating with thinly laminated shale. 40% Shale. Current laminated.
8/1*	0.30	59.60	Dolomite, medium gray to medium dark gray, micro-crystalline, medium bed. Current laminated. Yellowish gray weathered surface mottled with grayish black.
8/2 *	0.08	59.68	Dolomite, medium gray to medium dark gray, micro-crystalline, laminated. Oolites seen in thin section. Unit 8 is partly dolomitized limestone.
8/3*	2.45	62.13	Dolomite, medium dark gray, micro-crystalline, thin to thick bedded. Intraclasts in the bottom beds. Current laminated. Jointed and fractured. Yellowish gray to grayish orange pink weathered surface. Stylolites.

Unit	Thickness In Meters	Cumulative Thickness	Description
8/4	0.55	62.68	Dolomite, medium dark gray, microcrystalline, very thin bedded. Current laminated with alternate dark and light laminae.
8/5	1.33	64.01	Dolomitic sandstone, medium bluish gray, very fine grained, thin to medium bedded with occasional very thin beds. Current laminated with wavy internal laminae.
7*	0.65	64.66	Sandy dolomite, light to medium gray, very fine grained, very thin to thin bedded with shaly bedding planes. Current laminated, truncated cross-bedding. Pale yellowish brown weathered surface.
6/1*	0.35	65.01	Dolomitic sandstone, medium gray to brownish gray, very fine grained, very thin bedded. Ripple marked, current laminated.
6/2	1.20	66.21	Sandstone, grayish red, very fine grained, thin bedded with some very thin and laminated beds. Current laminated.
6/3	0.18	66.39	Sandstone, grayish red with a medium bluish gray surface, very fine grained, very thin bedded. Beds are lens shaped which pinch out and thicken. Planolites on lower bedding of some beds.
6/4	0.15	66.54	Sandstone, grayish red, very fine grained, thin bedded. <u>Planolites</u> on lower bedding plane.
6/5	0.40	67.29	Sandstone, grayish red with medium bluish gray blotches, very fine grained, very thin to thin bedded. Current laminated.
6/7	0.28	67.57	Sandstone, grayish red, medium bluish gray blotches, very fine grained, laminated to very thin bedded. Current laminated.

Unit	Thickness In Meters	Cumulative Thickness	Description
5*	0.35	67.92	Sandstone, grayish orange, very fine grained, laminated to very thin bedded with greenish gray to dark greenish gray bedding planes; occasional laminated shaly sandstone. Ripple marked.
4	0.63	68.55	Sandstone, grayish red, very fine grained, laminated to very thin bedded with laminated shaly sandstone.
3/1*	0.58	69.13	Dolomite, medium gray, microcrystalline, very thin to thin bedded. Current laminated. Yellowish gray weathered surface.
3/2	0.40	69.53	Sandy dolomite, medium gray, very fine grained, laminated to very thin bedded. Current laminated. Greenish gray surface.
3/3	0.18	69.71	Dolomite, medium gray, microcrystalline, thin bedded. Current laminated.
3/4	0.75	70.46	Sandy dolomite, medium gray, very fine grained, very thin to thin bedded with intervening laminated shale. Grayish orange weathered surface.
3/5	1.55	72.01	Dolomite, medium gray, microcrystalline, thin to medium bedded with occasional laminated beds. Current laminated; ripple marked; yellowish gray to grayish orange weathered surface.
			SMALL FAULT
2/1	0.48	72.49	Sandy dolomite, medium gray, very fine grained, very thin bedded with some laminated beds. Glauconitic sandstone, medium grained, very thin bed in the middle. Current laminated. Yellowish gray to grayish orange weathered surface.
2/2	0.20	72.69	Sandy dolomite, medium gray, very fine grained, thin bedded. Lenses of pure quartz 3 - 5 cm. thick, yellowish gray weathered surface.

Unit	Thickness In Meters	Cumulative Thickness	Description
2/3	0.25	72.94	Sandy dolomite, medium gray, very fine grained, very thin bedded. Current laminated. Sandstone stringers.
2/4	0.18	73.12	Sandy dolomite, medium gray, very fine grained, thin bed. Sandstone stringers 3 cm. thick.
2/5	1.85	74.97	Sandy dolomite, medium gray, very fine grained, thin to medium bedded with intervening laminated beds. Current laminated with alternate dark and light laminae. Pure quartz lenses some up to 10 cm. thick.
1/1	1.38	76.35	Shaly dolomite, medium gray to grayish blue, laminated to very thin bedded. Brecciated and shattered fault zone.
1/2*	1.25	77.60	Dolomite, medium gray, microcrystalline, medium bedded. Brecciated at the bottom whitish gray.
1/3	?		Quartzitic sandstone and dolomite, very fine grained pale brown and greenish gray. Fractured, jointed and shattered.
			SALTVILLE FAULT

BAYS MOUNTAIN - PORTERFIELD GAP SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			Top of unit is partly eroded and covered.
63*	5.00	5.00	Sandstone, grayish red to light brownish, silty to very fine grained, laminated to medium bedded, evenly very thin to thin bedded at the bottom becoming medium bedded at the top then thin bedded once again. Occasional laminated glauconitic sandstone; some bedding planes are greenish gray. Ripple marks and mud cracks are found nearly in every bed. Halite casts; rain prints; Rusophycus and Cruziana were found at the bottom and top of unit. Jointed.
62	0.95	5.95	Shaly sandstone, glauconitic, greenish gray to dark greenish gray and grayish red, silty to very fine grained, laminated to very thin bedded. 10% Shale.
61	1.70	7.65	Sandstone, pale brown with dark greenish gray bedding planes, silty to very fine grained, thin to medium bedded. Sinusites 2 mm. wide on upper bedding plane of one bed; jointed.
60*	0.33	7.98	Dolomitic oolite, light gray with a greenish gray bedding plane, medium bedded, grayish orange weathered surface; some parts are deeply weathered.
59*	23.50	31.48	Alternate very thin sandstone and laminated shale, grayish red, sandstone silty to fine grained with occasional medium grained glauconitic sandstone. Thin beds of dolomite and dolomitic shale in the middle, medium to dark gray in color. Bedding is uniform; glauconitic sandstone increases toward the top, with an increase in greenish gray shale. 20% Shale. Large Rusophycus were found close to the top in very thin silty sandstone.

Unit	Thickness In Meters	Cumulative Thickness	Description
58	1.15	32.63	Dolomitic sandstone, medium gray with a brownish weathered surface, very fine grained, laminated to thin bedded. Shiny muscovite on bedding planes. Planolites, 3 mm. wide, sinuous, on bedding planes at the top. Current laminations.
57*	2.45	35.08	Dolomite, sandy, dark gray with a rusty surface, very fine grained, very thin to medium bedded, sandstone stringers in dolomite. Planolites, 1 cm. wide and more than 5 cm. long on lower bedding plane.
56	1.98	37.06	Sandstone, grayish red, silty to very fine grained, laminated to very thin bedded; 13 cm. of light gray shale in the middle; sandstone at the bottom is dolomitic. Dolomitic sandstone fractured.
55	8.80	45.86	Dolomite, medium gray with grayish orange weathered surface; very fine grained, very thin to thick bedded; dolomite is full of sandstone stringers. Unit is faulted 3.5 meters from the bottom. Four horizons of Skolithos 2 mm. wide and up to 2 cm. long in a medium bed at the bottom; unit is fractured and jointed.
54*	2.20	48.06	Dolomite and shaly dolomite, light to medium gray, laminated to thin bedded but mostly very thin, thin beds in the middle of unit. Halite casts some up to 1.5 cm. wide. Top of unit looks flasered.
53	1.65	49.71	Sandstone, grayish red to pale brown, silty to very fine grained, laminated to very thin bedded, bedding planes are shiny due to the presence of mica. Ripple marked and current laminated.
52	0.80	50.51	Dolomite, medium gray with a grayish orange weathered surface, laminated to very thin bedded. Mostly laminated.

Unit	Thickness In Meters	Cumulative Thickness	Description
51*	1.35	51.86	Quartzitic sandstone, pale brown to grayish red with a grayish orange weathered surface, silty to very fine grained; grayish bedding planes, very thin to thin bedded. Ripple marked, current laminated. _Rusophycus_ found close to bottom.
50	7.50	59.36	Sandstone, and shaly to silty sandstone, grayish red, very fine grained, sandstone is thin bedded in the middle of unit; shaly sandstone top third of unit. Laminated to very thin bedded. Some sandstone beds about 50 cm. thick in the middle are porous. 10% Shale. Shaly sandstone looks flasered; ripple marked.
49	2.45	61.81	Dolomitic sandstone, pale yellowish brown to very light gray, with grayish orange weathered surface, very fine grained, medium bedded at the bottom, very thin to thin at the top. Ripple marked; fractured and jointed. Current laminated.
48	6.30	68.11	Sandy dolomite, medium to dark gray with grayish orange weathered surface, very fine grained, very thin to massive, bedded; sandstone stringers in dolomite. Fractured and jointed.
			FAULT
47	3.25	71.36	Sandstone, grayish red, silty to very fine grained, laminated to thin bedded but mostly very thin with shaly bedding planes, evenly and uniformly bedded. Ripple marked; mud cracks; flasered, halite casts?
46	14.40	85.76	Alternate very thin bedded sandstone and laminated shale, greenish gray, very fine grained sandstone. 40 - 50% Shale. Flasered; unit not very well exposed.

Unit	Thickness In Meters	Cumulative Thickness	Description
Cov-ered	61.20	146.96	From the debris it is made up mostly of very thin bedded alternate sandstone and shale, mostly grayish red and greenish gray, probably some dolomite beds. Ripple marks and worm burrow casts in specimens in the debris.
45	1.15	148.11	Sandstone, light grayish orange, silty to very fine grained, medium bedded at the top with very thin bedded medium gray sandstone at the bottom. Fractured and jointed; current laminated.
44/1	4.75	152.86	Sandy dolomite, medium gray, very fine grained, thick to medium bedded, about 3 m. at the top, the unit is deeply weathered to a dark yellowish orange color. Current laminated.
44/2	2.05	154.91	Sandy dolomite, medium gray, very fine grained, very thin to thin bedded. Current laminated.
43	1.63	156.54	Alternate, very thin bedded sandstone and laminated shale, greenish gray with pale brown shiny bedding planes; there is a pale brown, thin sandstone bed at the bottom. Flasered.
42*	5.25	161.79	Alternate very thin bedded sandstone and laminated shale, grayish red at top and dusky yellow at the bottom of the unit; very fine grained sandstone, evenly bedded. Flasered at the top; mud cracks in a red bed; halite casts bottom of unit in a very thin sandstone bed.
41	1.85	163.64	Quartzitic sandstone, pale yellowish brown, silty to very fine grained, thick bedded at the bottom and very thin to laminated at the top. Ripple marked; Planolites 3 - 5 mm. wide sinuous and straight on bedding planes of some beds.

Unit	Thickness In Meters	Cumulative Thickness	Description
40	7.70	171.34	Dolomite, medium gray, very fine grained, medium to very thick bedded with sandy bedding planes. The unit becomes very thin bedded at the top with sandstone beds and olomite showing differential weathering.
	13.30	184.64	COVERED
39	27.30	211.94	Sandstone, grayish red to purple, very fine grained, thin to medium bedded at the bottom with 5 m. of shale and intervening very thin bedded sandstone at the top. Bottom beds are fractured and jointed; current laminated; planolites on some bedding planes.
38	2.50	214.44	Dolomite, medium gray, ver fine grained, medium bedded; alternate deeply weathered and resistant layers. Weathered surface is whitish; deeply weathered beds are dark yellowish orange. Fractured and jointed; some beds show modular weathering.
37	1.80	216.24	Sandstone, grayish to grayish orange with a dark grayish orange weathered surface; very fine grained; medium bedded, looks massive. Fractured and jointed.
36	9.30	225.54	Dolomitic limestone, light to medium gray, very fine grained laminated to thin bedded but mostly very thin; dolomitic limestone is interbedded with sandstone, grayish orange. Some beds in the unit are deeply weathered.
35	7.20	232.74	Quartzitic sandstone, light to medium gray, very fine grained, very thick to thick and medium bedded at the top. The unit is dolomitic at the top. Fractured and jointed, looks massive.
34	22.00	254.74	Dolomite, medium gray, very fine grained, very thin to medium bedded, sandstone stringers are abundant. A Large part of the unit is brecciated and deeply weathered at the top and bottom.

Unit	Thickness In Meters	Cumulative Thickness	Description
			FAULT
33	1.35	256.09	Dolomite, medium gray, very fine grained, laminated to thin bedded at the bottom and medium bedded at the top with sandstone stringers. Internal dark and light laminations. Fractured and jointed.
32	0.75	256.84	Silty shale, dark greenish gray, laminated, interbedded with very thin bedded, very fine grained sandstone. Jointed; deeply weathered top 12 cm.
31	0.77	257.61	Shale, grayish red and light greenish gray, laminated, with 12 cm. of very thin bedded siltstone.
30	0.93	258.54	Sandstone, grayish red, silty to very fine grained, very thin bedded at the bottom; unit becomes greenish gray silty shale, laminated top 38 cm. Sandstone is interbedded with grayish red laminated shale 40% Shale. Ripple marked, mud cracked.
29	1.25	259.79	Sandstone, grayish red, very fine grained, very thin bedded alternating with shale at the bottom; unit becomes greenish gray and more shaly at the top. 30% Shale. Flaser bedded.
28	1.05	260.84	Shaly siltstone, greenish gray mottled with grayish red, very thin to laminated; deeply weathered and grayish red at the top. Ripple marked, mud cracks.
27	1.05	261.89	Shaly siltstone, grayish red, laminated, deeply weathered at the top.
26	1.35	263.24	Siltstone, grayish red at the bottom and dusky yellow to moderate brown at the top of unit, laminated to very thin bedded, with greenish gray bedding planes. Ripple marked; current laminated.
25	1.32	264.56	Sandstone, grayish red, very fine grained, laminated to medium bedded; upper 50 cm. are silty shale. Mud cracks; current laminated. Jointed and fractured.

Unit	Thickness In Meters	Cumulative Thickness	Description
24	1.83	266.39	Sandstone, grayish red, silty to very fine grained, laminated to very thin bedded; shaly bedding planes, silty shale top 50 cm. of unit. Ripple marked, mud crack polygous 25 cm. across associated with halite crystal casts up to 1 cm. wide. Worm tracks ½ cm. wide and about 5 cm. long and straight.
23	1.58	267.97	Silty sandstone, grayish red very fine grained, laminated; silty shale lower 38 cm. Current laminated, flaser bedding mud cracks.
22*	2.48	270.45	Sandstone, grayish red, very fine grained, very thin to medium bedded at the bottom becoming laminated at the top; sandstone becomes shaly top 50 cm. of unit. Ripple marked, halite crystal casts and molds on bedding plane close to the top. Nearly every bed has mud cracks.
			FAULT
21	4.25	274.70	Sandstone, grayish red to purple, very fine grained, very thin to medium bedded, looks massive. Current laminated; <u>Planolites</u> on some bedding planes are abundant ½ cm. wide straight and sinuous; worm tracks of the same size.
20*	1.27	275.97	Sandstone, medium gray to grayish orange, very fine grained, very thin to medium bedded at the bottom. A 12 cm. thick siltstone bed at the top is completely burrowed with <u>Sinusites</u>. <u>Sinusites</u> also below this bed.
19	2.20	278.17	Dolomite, medium to dark gray, very fine grained, thick bedded at the bottom and medium bedded top of unit. Current laminated; looks modular fractured and jointed.

Unit	Thickness In Meters	Cumulative Thickness	Description
18	2.38	280.55	Dolomite, sandy, light to medium gray, very fine grained, very thick at the bottom to very thin bedded and shaly at the top. Sinusites on bedding plane of one bed. Shattered jointed and fractured.
17	6.90	287.45	Dolomite, medium gray, very fine grained, very thin to thick bedded, bluish gray bedding planes; top of unit deeply weathered; some beds are laminated due to differential weathering due to the presence of sandstone stringers; bottom beds are sandy and laminated. Mud cracks in a thick dolomite bed.
16	0.86	288.31	Sandstone, grayish red, very fine grained, laminated to very thin bedded, shaly bedding planes. Ripple marked, mud cracks nearly in every bed.
15	2.60	290.91	Dolomite, sandy, light to medium gray, thick to medium bedded at the bottom becoming very thin bedded at the top. Current laminated fractured and jointed.
14	1.15	292.06	Sandstone, dolomitic, very fine grained, light grayish with grayish orange weathered surface. Unit is massive, fractured; fine internal laminations probably algal.
			FAULT
13	3.85	295.91	Dolomite, light to medium gray, very fine grained, thin bedded at the bottom and medium bedded at the top; weathered surface is grayish white; unit is deeply weathered in the middle. Current laminated.
12	8.78	304.69	Dolomite, sandy, medium to dark gray, very fine grained, medium to thick bedded, weathered surface is grayish white. Fractured and jointed, unit may be faulted close to bottom.

Unit	Thickness In Meters	Cumulative Thickness	Description
11*	4.00	308.69	Dolomite, sandy, medium gray, very fine grained, laminated to medium bedded, sandstone stringers in dolomite beds occasional laminations between beds. Rusophycus and Cruziana; ripple marked, micro cross-bedding.
10	3.00	311.69	Siltstone, calcareous, grayish white to light gray, laminated to thin bedded; weathered surface grayish orange; some horizons in the middle and top are deeply weathered; limestone bed 12 cm. thick in the middle. Fractured and jointed.
9	2.40	314.09	Sandstone silty, grayish white at bottom to pale brown at the top, very fine grained, very thin to thick bedded; greenish gray bedding at bottom while at the top they are grayish red; dolomitic sandstone beds in the middle. Mud cracks abundant in beds at the top of unit.
8*	5.07	319.16	Silty sandstone, grayish red, very fine grained, laminated at the top to thick bedded at the bottom; laminated shale top 50 cm. Ripple marks and mud cracks nearly in every bed; halite crystal casts; current laminated.
7	2.48	321.64	Shaly dolomite, medium gray, laminated, looks massive. Current laminated.
6	3.85	325.49	Calcareous siltstone, pale yellowish brown, medium bedded at the bottom, becoming very thin to laminated at the top; some beds at the top are deeply weathered. Some beds are porous.
5	1.30	326.79	Calcareous siltstone, grayish red at the top and pale yellowish brown at the bottom, thin to medium bedded. Current laminated; fractured and jointed.

Unit	Thickness In Meters	Cumulative Thickness	Description
4	2.20	328.99	Sandstone, silty, grayish red, very fine grained, thin to medium bedded; grayish red shaly bedding planes. Mud cracks on some beds.
3	0.68	329.67	Shaly dolomite, medium to dark gray, very fine grained, laminated with a 10 cm. dolomite bed at the bottom. Jointed.
2	2.82	332.49	Calcareous siltstone, grayish red, medium bedded at the bottom becoming laminated shaly siltstone at the top. Current laminated.
1	1.75	334.24	Calcareous siltstone, grayish red, laminated to thin bedded; a horizon 25 cm. thick is dusky yellow and deeply weathered at the top. Fractured and jointed; axis of anticline.
?			COVERED
			DUMPLIN VALLEY FAULT

BAYS MOUNTAIN - SHOOKS GAP SECTION

Unit	Thickness In Meters	Cumulative Thickness	Description
			Pumpkin Valley Shale and the top of the Rome are not exposed in this section.
40	3.00	3.00	Sandstone, grayish orange, very fine grained, laminated to very thin bedded. Folded.
39	2.40	5.40	Sandstone, dark yellowish orange, very fine grained, very thin to thin bedded. Competent.
38	2.75	8.15	Sandstone, olive gray very fine grained very thin bedded. Beds are competent.
37	2.05	10.20	Siltstone, grayish orange, thin bedded at bottom becoming laminated and unconsolidated at the top, some siltstones have a limonitic color. Reddish clay very thin beds at the top are probably due to weathering of carbonate beds.
36	2.40	12.60	Sandstone, grayish red to purplish, very fine grained, very thin to medium bedded, some beds are light grayish orange with purplish surfaces. Fractured and jointed. Unit is competent.
35	1.50	14.10	Alternate laminated shale and very thin bedded sandstone grayish pink with a brownish weathered surface.
			FAULT
34	0.75	14.85	Sandstone, silty, grayish red, very fine grained, thin bedded. Fractured and jointed.
33	3.55	18.40	Alternate laminated shale and very thin bedded very fine sandstone dark greenish gray; sandstone becoming thin bedded at the top and grayish red. Glauconitic laminations in siltstone beds at the bottom.

Unit	Thickness In Meters	Cumulative Thickness	Description
32*	0.80	19.20	Dolomitic conglomeritic oolites, light gray, medium bedded with few very thin and thin beds. Pebbles are very fine at the bottom becoming larger at the top. Differential weathering in which the pebbles stand out. Cross bedded. Unit is glauconitic.
31	1.50	20.70	Alternate very thin bedded siltstone and laminated shale, greenish gray. Siltstone beds have a limonitic surface.
30*	1.50	22.20	Glauconitic siltstone and very fine sandstone, dark greenish gray, very thin to thin bedded.
29	0.60	22.80	Shale, dark greenish gray, thinly laminated. Flakey.
28*	0.55	23.35	Glauconitic siltstone, dark greenish gray, very thin bedded. Pale brown weathered surface.
27	1.10	24.45	Shale, greenish gray, thinly laminated bottom 50 cm., interbedded with pale reddish brown, very thin bedded siltstone at the top Shale is flakey and friable.
26	0.65	25.10	Glauconitic siltstone, dark greenish gray, thin bedded. Weathers to olive gray color.
25	4.25	29.35	Alternate laminated shale and very thin bedded siltstone, medium gray. Some beds have abundant glauconite. Glauconitic laminae in siltstone beds. Organic structures masked by folding and contortion.
24	1.10	30.45	Shale, medium gray, thinly laminated with a 10 cm. thick siltstone bed at the top. Shale is nearly slaty; fractured.

Unit	Thickness In Meters	Cumulative Thickness	Description
23*	6.60	37.05	Siltstone, dark yellowish orange, very thin bedded with laminated shale and occasional thin siltstone beds; light greenish gray bedding planes. Glauconitic laminae in some beds. Some beds weather to a limonitic color. Folded and contorted. Possible bedding plane faults.
22	3.25	40.30	Siltstone, grayish orange, very thin bedded. Weathers to a limonitic color.
21	0.90	41.20	Siltstone, light grayish orange, thin bedded. Weathers to a brownish limonitic color. Fractured.
20	3.75	44.95	Siltstone, grayish orange, very thin bedded with laminated shale. Weathers to a limonitic color. Partly covered.
19	0.75	45.70	Siltstone, light grayish orange, very thin to thin bedded. Weathers to olive gray color. Fractured.
18	0.90	46.60	Siltstone, grayish orange, very thin bedded, with occasional laminated and thin beds. Fractured and jointed. Small syncline.
17	0.20	46.80	Siltstone, grayish red, laminated.
16	0.50	47.30	Shale, light greenish gray, thinly laminated.
	?		COVERED
15	0.65	47.95	Siltstone, grayish red, very thin bedded with occasional laminated shale.
14	0.55	48.50	Alternate laminated siltstone and shale, grayish blue green, with occasional pale red siltstone with limonitic surface.
13	0.75	49.25	Alternate very thin bedded grayish red siltstone and laminated greenish gray shale.

Unit	Thickness In Meters	Cumulative Thickness	Description
	?		COVERED
12	1.50	50.75	Siltstone, pale yellowish brown laminated to thin bedded, with very thin beds at the top and limonitic surfaces. Fractured and jointed.
11	0.30	51.05	Alternate laminated siltstone and shale, grayish red. Shale is flakey.
10	0.63	51.68	Siltstone, dark yellowish orange, very thin to laminated, with light greenish gray, laminated siltstone. Fractured.
9	0.25	51.93	Siltstone, light greenish gray, laminated, friable with limonitic surfaces.
8	1.00	52.93	Siltstone, light brown, thin bedded at the bottom becoming very thin bedded and then laminated at the top with a change to purplish color.
7	0.30	53.23	Alternate laminated, siltstone and sandstone, light brown.
6	0.75	53.98	Siltstone, light brownish, laminated to very thin bedded with occasional, grayish blue green sandstone laminations.
	?		COVERED
5	2.00	55.98	Siltstone, varicolored with grayish pink to very pale orange to white, laminated to very thin bedded. Iron oxide band folded and distorted at the top of unit.
4	0.03	56.01	Iron oxide band, silty, limonitic color. Fractured, folded and faulted.
3	3.50	59.51	Siltstone, varicolored, laminated to v very thin bedded. Laminae are clear due to the different colors.
2	0.13	59.64	Iron oxide, silty, thin bed, hematitic and limonitic colors. Fractured.

Unit	Thickness In Meters	Cumulative Thickness	Description
1	0.75	60.39	Mudstone, light greenish gray, to vari-colored at the top, laminated. Laminae are clear due to change in color.
	?		COVERED
			DUMPLIN VALLEY FAULT

VITA

Nabil Fahmi Samman was born in Jerusalem, Palestine, on April 20, 1944. He attended elementary school in that city and was graduated from Saint George's School in 1961. The following September he entered the American University of Beirut in Lebanon, and in June 1965, he received a Bachelor of Arts degree in Geography. In the summer of 1966, he accepted a teaching assistantship at the American University of Beirut, where he received a Master's degree in Geology in June 1968. He was employed as a lecturer in the Geography Department at the University of Jordan from September 1968 to September 1970.

He entered the Graduate School at the University of Tennessee in September 1970, where he received the Doctor of Philosophy degree with a major in Geology in August 1975. He is a member of the American Association of Petroleum Geologists, Society of Economic Paleontologists and Mineralogists and Sigma Gamma Epsilon.

He is married to the former Safiya Ataya of El-Deeb, Palestine and has one daughter named Lama.